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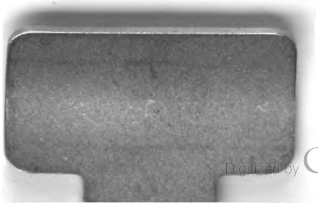

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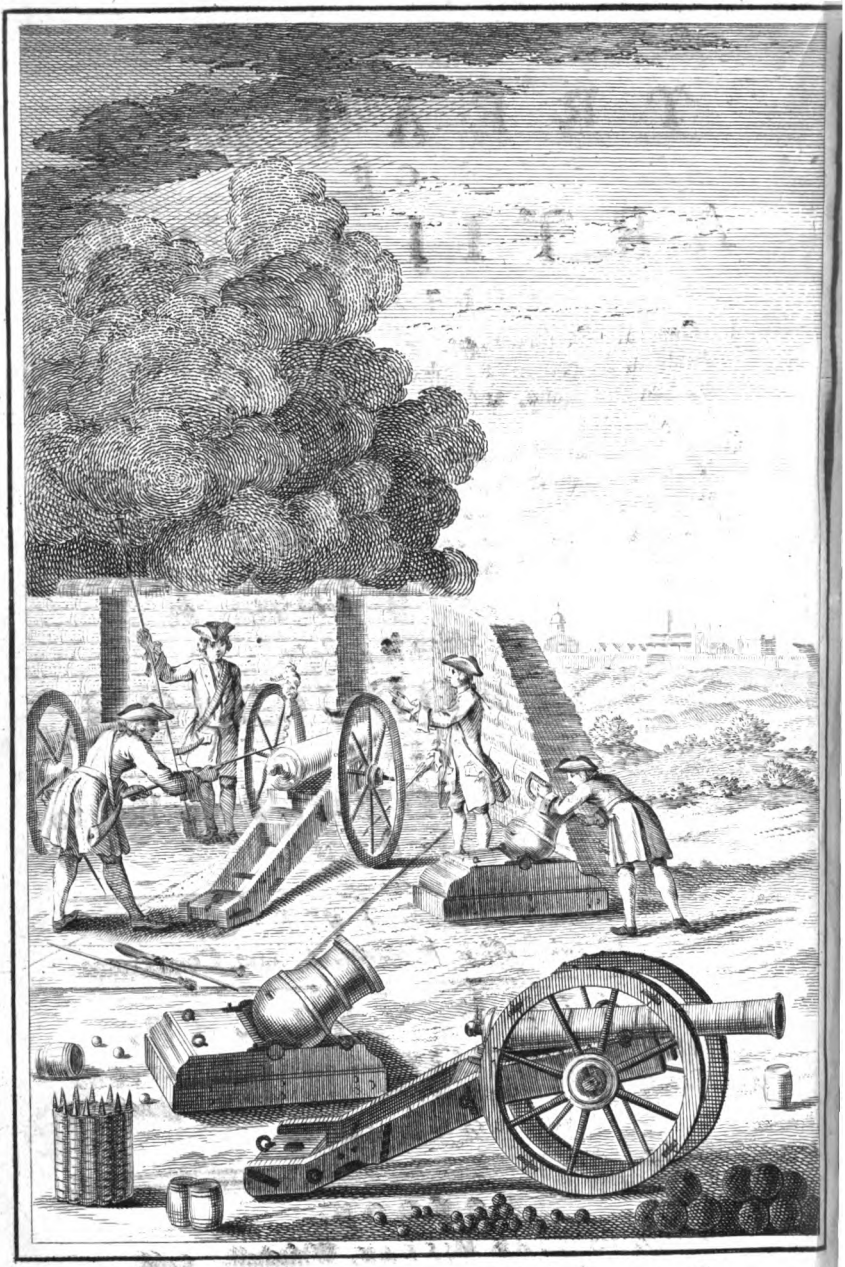

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A TREATISE OF ARTILLERY:

CONTAINING

I. General Conſtructions of Braſs and Iron GUNS uſed by Sea and Land, and their CARRIAGES.

II. General Conſtructions of MORTARS and HOWITZES, their BEDS and CARRIAGES.

III. DIMENSIONS of all CARRIAGES uſed in ARTILLERY.

IV. EXERCISE of the REGIMENT at Home, and SERVICE Abroad in a SIEGE or BATTLE.

V. Its MARCH and ENCAMPMENT, AMMUNITION, STORES, and HORSES.

VI. Laſtly, The neceſſary LABORATORY WORK for FIRE-SHIPS, &c.

To which is prefixed,

An INTRODUCTION,

WITH

A THEORY of POWDER applied to FIRE-ARMS.

The SECOND EDITION,
With large Additions, Alterations, and Corrections.

By JOHN MULLER,
Profeſſor of ARTILLERY and FORTIFICATION,
And Preceptor of Engineering, &c. to his Royal Highneſs the Duke of GLOUCESTER.

LONDON:
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TO

HIS ROYAL HIGHNESS

The Duke of GLOUCESTER, &c.

THIS WORK

Is moſt humbly Dedicated,

BY

His Royal Highneſs's

Moſt devoted,

Moſt obliged, and

Moſt obedient Servant,

JOHN MULLER.

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CONTENTS.

☞ The new Articles are marked with an Aſteriſm *.

* *INTRODUCTION, the origin of artillery* Page i
* *The firſt guns invented by king* Vitey *in* 85 ibid.
* *Light field pieces introduced by col.* Weideman iv
Experiments on the ranges of guns —— v—ix
Table I, II, III, *length and weight of* French *guns* ix
Gen. Armſtrong's *experiments on the length of a* 24 *pounder* xi
General Williamſon's *experiments on the beſt length and charge of an* 18 *pounder* —— —— xiii
The author's experiments with mortars on the beſt figure of chambers, and on the beſt ſituation of the vent xix
Theory of powder, and its application to fire arms xxvi
* *A new conſtruction of* { *braſs guns for land ſervice* xxxvi / *light iron field pieces* xxxvii
A table of the greateſt velocities, and the greateſt ranges, which the different calibers can poſſibly have xxxviii
* *A table of the diſtances that ſhips may be ſeen, from one yard to* 50, *by the obſerver's eye, above the ſurface of the water* —— —— —— xxxix

PART I.

* *Of artillery, containing the weights and meaſures* 1
Diameters of the ſhots and bores of guns —— 6
* *Ditto of the* French *expreſſed by* { *their* / *our* } *meaſure* 8, 10
* *Table of* { *grape ſhot, from* 1 *to* 39 *ounces* 12 / *leaden bullets from* 1 *to* 39 *in the pound, according to the author* —— 14
The ſame table according to Sir Jonas Moor — ibid.
The author's experiments on powder meaſures —— 15
* *Tables of cylindric powder meaſures, from* 1 *ounce to* 39 *pounds, according to the author* —— 16
* *Tables of ditto* { *when the diameter is to the axis, as* 2 *to* 3 —— —— 17 / *according to Sir* Jonas Moor 18, 19, 20

* *Inveſti-*

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* *Inveſtigation of a general rule for finding the ſums of ſeries's, applied to the finding the number of ſhot contained in any pile* —— —— Page 21
* *A table of the number of ſhot in* 1620 *piles* — 26

PART II.

Conſtruction of guns —— —— 26
Names of the ſeveral parts of a gun —— 27
Gen. Armſtrong's *conſtruction of braſs and iron guns* 29
Examination on the ſeveral parts of a gun —— 33
General conſtruction for braſs battering pieces —— 46
To find the weight of metal of a gun —— 49
* *Length and weight of old and new battering pieces* 50
Conſtruction of iron battering pieces, with a table of their length and weight —— —— 52
General conſtruction of iron ſhip guns —— 53
* *A table of their length and weight* —— 54
* *General conſtruction of braſs ſhip guns, with a table of the length and weight of old and new* —— 56
* *A table, comparing the weight of the old and new guns of all the different rates in the preſent eſtabliſhment* 58
* *Number and caliber of guns on board the ſeveral men of war* —— —— —— 60
Conſtruction of light field pieces, with a table to compare the length and weight of the preſent with the new 61

PART III.

Conſtructions of mortars and howitzes —— 65
Dimenſions of { *the preſent land mortars* —— 67
ſea mortars —— —— 68
howitzes —— —— 69
Remarks on the conſtructions of mortars —— 70
General dimenſions for new land mortars —— 74
Remarks on theſe dimenſions —— —— 75
To find the weight of metal and powder —— 78
General dimenſions for howitzes —— 80
Weight of howitzes and powder —— 82

Of

Digitized by Google

Of sea mortars —— —— Page 84
General construction of sea mortars —— 85
Weight of sea mortars and powder —— 86
General construction of shells —— —— 89
Dimensions of stone mortars —— —— 91

PART IV.

Construction of { *gun* —— — 94
ship and garrison — 95
Dimensions of ship and garrison — 96
General construction of such —— — 97
Irons of ship —— —— — 99
Construction of travelling —— — ibid.
General dimensions of travelling — — 103
Iron work of travelling —— — 106
Dimensions of wheels for these — — 108
} *Carriages.*
Tools necessary for loading and proving guns 110
Construction of carriages for light field pieces 112
Dimensions of { *a galloper carriage* —— 115
limbers —— —— 116

PART V.

Of mortar beds and howitz carriages —— 119
Dimensions of { *land mortar beds* —— ibid.
sea mortar beds —— 123
an eight inch howitz carriage 124

PART VI.

Different sorts of carriages used in artillery 125
Dimensions of a { *tumbrel* —— —— ibid.
powder cart —— 127
ammunition waggon —— 128
block carriage —— 131
sling waggon —— 134
truck carriage —— 137
travelling forge —— 138
pontoon carriage —— 140
pontoon —— —— 141

The

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The gin —— —— Page 143
Petards —— —— 145

PART VII.

Practice of artillery at home, and service in war 147, 148
Mortar practice —— —— 153
Practical rules for horizontal ranges —— 156
The service of artillery in { *a land engagement* 160 / *an attack* —— 163
* *Ricochet batteries* —— —— 170
* *Batteries on a glacis* —— —— 171
* *Mortar batteries* —— —— ibid.
* *Battery* { *in moraſs* —— —— 172 / *upon a rock* —— —— ibid.

PART VIII.

Artillery and ſtores neceſſary for a field equipage 175
Quantity of powder and ſhot for an army —— 176
Powder and ſhot for muſkets, carbines, and piſtols 177
Number of horſes uſed { *for guns* —— 178 / *in the campaign of* 1747 179
Stores for the army in 1747 —— 182
General Belford's *march of the artillery* —— 191
The manner of forming a park of artillery — 194
Laboratory works —— —— 199
Deſcription of { *a fireſhip, and fitting it up* 206 / *and manner of preparing ſtores* 207
Diſpoſition of ſtores on board, when laid for firing 210
Stores for a fireſhip of 150 *tons* —— 212
Compoſition for preparing the ſtores of a fireſhip 213
* *Conſtruction of batteries, with a table of the tools, materials, and number of men, to finiſh them in one night* 214

INTRO-

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INTRODUCTION.

THE origin of fire arms and artillery is owing to the diſcovery of gunpowder; but when this was, or in what country, we are ignorant of: it is however probable, that it muſt have been in the eaſtern part of the world, becauſe ſaltpetre, which is the principal ingredient, is found in great plenty in ſome provinces on the ſurface of the earth, and from thence is brought to *Europe*. Ever ſince its uſe has been known; and ſaltpetre being mixed with ſulphur, or ſome other combuſtible ſubſtance, either by chance or otherwiſe, produced a power by its exploſion not known before, whereby bodies could be thrown to a great diſtance.

It is generally ſuppoſed that the *Chineſe* were the firſt that made this diſcovery; for *Ulano Valeſco*, a *Spaniſh* author, mentions, that powder and guns were found in *China* in the year 85, by king *Vitey*; but whether it was known before in any other country is uncertain.

The firſt diſcovery of powder in *Europe* was made by *Bartold Schwartz*, a monk, at *Mentz*, in 1320, by accident; being a chymiſt, he happened to mix ſome ſaltpetre with ſulphur in a mortar, and covered it with a ſtone; the compoſition accidentally taking fire, the exploſion blew the ſtone to a conſiderable diſtance. This ſuggeſted the notion, that if this compoſition was properly confined, it might be uſeful in the attack and defence of places: and from thence the invention of guns may be dated in *Europe*.

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Roger Bacon, who lived about 50 years before, mentions a compoſition known in his time, by which thunder and lightning could be imitated: *Schwartz* was the firſt who applied it to military uſes.

It is ſaid that the *Venetians* made the firſt uſe of guns at the ſiege of *Claudia Jeſſa*, now called *Chioggia*, in 1366, which were brought there by two *Germans*, with ſome powder and leaden balls; but father *Daniel* proves from records, that the *French* had guns in 1338. As the invention of guns is ſo immediately connected with that of powder, it could not well be otherwiſe than that *Shwartz* was the inventor of both; and that they were from thence carried to *France*, and afterwards to *Italy*.

Some authors ſay, that the firſt guns were made of iron bars laid lengthways, and kept together with ſtrong iron hoops; and others, with thin ſheets of iron rolled up together and hooped; but which way they were made, it muſt have been in a rude and imperfect manner, like the firſt eſſays of many new inventions.

The firſt guns were but ſmall, and their ſhot of lead; but afterwards, when their uſe became better known, they were caſt of gun metal, and of extraordinary ſize; and their ſhot were made of ſtone: for the *Turks* had ſome at the ſiege of *Conſtantinople*, that threw a weight of 500 lb. and *Louis* XI. had one caſt of the ſame ſize; many others are mentioned in hiſtory, who carried ſhots that weighed from 80, 90, to 100 pounds.

But as theſe guns were ſo very heavy, and could not be tranſported without great difficulty, they have been reduced to ſmaller calibers, and made their ſhot of iron. Since that time the largeſt caliber that were uſed was a 48 pounder; but at preſent no larger are made in the land ſervice than 24; and at ſea 42 pounders.

It was long imagined, that the more powder a cannon was loaded with, the greater its execution would be; for which reaſon they were loaded with as much powder as their

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their ſhot weighed, and to reſiſt ſo great a force, they were made very heavy, and of a great length, in order to give time to the powder to burn all before the ſhot left the piece.

This great charge was diminiſhed afterwards to two thirds, and then to one half, without leſſening the weight of the guns, or their length. The chevalier *Belidor* made ſome years ago ſeveral experiments relating to the charge of battering pieces, whereby he found that one third of the weight of the ſhot was ſufficient, and the *French* uſed no more during the two laſt wars: it is very probable that leſs might do; for ſome experiments were made at *Woolwich* with light field pieces, and it was found that one fourth and even one fifth was ſufficient for the charge of theſe pieces.

Notwithſtanding the great importance it would be to a nation to have its artillery carried to ſuch perfection, as to make uſe of as little metal and workmanſhip as poſſible, and at the ſame time to bring as many and as large calibers into the field as others, thereby reducing its immenſe expence to as little as is abſolutely neceſſary; yet it will be found upon examination, that very little improvement has been made in the proportions of guns ſince *Dilichius*, a *German*, who wrote near 200 years ago.

It is true *St. Remy*, a *French* author, publiſhed in 1723 the moſt compleat and extenſive Treatiſe of Artillery, in two volumes in quarto, that is extant; which has ſince been much improved in the laſt *Paris* edition, in three volumes, publiſhed in 1745, containing all the improvements made in the artillery ſince the firſt edition: but as it is only a collection of memoirs he received from the different artificers employed in theſe works, and who had no other knowledge than bare imitation, it could therefore not be expected that what they tranſmitted to him was grounded upon ſuch mechanical principles as depended upon mathematics, without which no real improvements can be made.

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All the authors that wrote ſince have done no more than copied his works in an imperfect manner, even the *German* authors follow him; though it is plain that the *French* have chiefly copied *Dilichius:* for their field carriages are exactly the ſame to this day as he has delineated them in his work; and as to the alterations they have made in the proportions of guns, they are trifling and very little to the purpoſe.

If we conſider the various lengths and weights that have been given to pieces of artillery at different times by all nations, it will appear, that no principle is ſo uncertain and unſettled as that upon which the artillery artificers have grounded their conſtructions. For in queen *Elizabeth*'s time they made ſome 18 pounders 24 feet long, caſcable included, ſuch as the culverin in *Dover-Caſtle*, and that at *Nancy*; and in king *Charles* the ſecond's, Count *Mansfield* made ſome 6 pounders that weighed but 180 lb. and 25 pounders of 700 lb. as is related in the account of the ſiege of *Breda* by the *Spaniards* under the command of *Spinola*; and about the ſame time the *Spaniards* caſt ſome others not much heavier; one of them we had at *Woolwich* was 7 feet long, weighed only 21 : 3 : 4, and carried a ſhot of about 41 pounds of our weight.

Though theſe light pieces were then highly eſteemed for their eaſy carriage and facility of working, yet much heavier and longer have been made ever ſince without any manner of reaſon, till 1744, when Colonel *Weideman*, a *German*, brought light pieces in uſe again as a new invention of his own. His pieces were made of ſheets of copper rolled up and ſoldered together; they were ſo very light, that a 6 pounder weighed no more than two hundred and a half, and yet ſtood all the proofs that were required.

This gave riſe to our light field pieces; but it was not without great difficulty that they were received, and no leſs than the expreſs command of his royal highneſs the late duke of *Cumberland* could have prevailed over the

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the ſervile attachment for an old eſtabliſhed cuſtom, though ever ſo erroneous, which, when once covered by the veil of time, becomes in a manner ſacred.

But even lighter field pieces than the preſent might be uſed; for on the 12th of *June* 1751, ſome experiments were made on *Putney-Common* by baron *Stark*, a *German*, with a piece made of a new metal of his invention; which piece was a 6 pounder of 3 feet and a half long, and weighed 3 : 2 : 0, as he ſaid, and it was fired 300 rounds in three hours and 45 minutes, being loaded each time with a pound and a quarter of powder, without receiving the leaſt damage.

This trial being reported to lord *Ligonier*, then maſter general of the ordnance, he and the reſt of the principal officers of the board reſolved to try our light 6 pounders, in order to know whether they would ſtand the ſame trial or not; and accordingly, on the 15th of *June*, my lord pitched upon one amongſt thoſe that had been uſed at the battle of *Lafeldt*. This piece was four feet and a half long, and weighed 4 : 3 : 0; and after being fired 300 rounds in three hours and 27 minutes, loaded with the ſame charge as that above, was found not to have received the leaſt damage. The ſame trial has been repeated afterwards with a gun of the ſame dimenſions as the former, which had been made by another founder, and it ſucceeded equally as well.

Theſe trials ſhew, that thoſe light pieces are ſufficiently ſtrong for any action ever ſo obſtinate; and that pieces in general may be made lighter than they are at preſent, appears from ſeveral other trials made ſince with light braſs pieces, according to my conſtruction, as will be ſhewn hereafter.

It is ſaid that ſuch light pieces would not do for battering breaches, nor on board of ſhips, becauſe of their recoiling too much; but it ſhould be conſidered, that batteries made upon theſe occaſions are always, or ought to be near the object, and the charges now uſed are but half the former, becauſe a ſhot, which has a ſufficient

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velocity juſt to enter the wall, ſhakes it more and deſtroys it ſooner than if the velocity was much greater. This is a matter of fact grounded upon experience.

It is ſuppoſed at preſent, that no leſs caliber than a 24 pounder will do to make a breach: and it may ſo happen, that the heavy pieces cannot be carried through bad roads, as in *America*, or over high hills, as in *Scotland*. Upon theſe occaſions it ſeems to be abſolutely neceſſary to have light pieces: for which reaſon we have given a new conſtruction of light pieces in page 62, where the weight of a 24 pounder is 18 : 1 : 5; which differs in ſome things from thoſe uſed at preſent: becauſe mine are made the ſame number of calibers long, and their weights in proportion to that of their ſhot, as we ſhall prove hereafter they ſhould be; whereas the large calibers of the preſent are made ſhorter and lighter in proportion than the ſmall; and it has been found by experience, that the preſent light 24 pounders recoil too much, let the hind part of the platform be ever ſo much raiſed.

Artillery has hitherto been conſidered merely as practical, without conceiving that for want of the mechanical principles, deduced from mathematics, no improvements can poſſibly be made. For all the experience of the artillery officers cannot be of any uſe in the conſtruction of pieces, as their buſineſs is to make the beſt uſe of them, and not how they are made, neither are they ever conſulted upon that ſubject.

To put the artillery upon a better footing than it has hitherto been, proper experiments ſhould be made in time of peace, and by ſuch as have ſufficient knowledge, ſo as to be able to draw juſt inferences, which is ſeldom the caſe, as it appears by thoſe hitherto made, and which will be inſerted hereafter, where it will be ſhewn how little the moſt of them may be relied on.

It is certain, that in moſt caſes common geometry and the principles of mechanics is ſufficient; but there are others which cannot be determined without the higher principles

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principles of mathematics. For how can the velocities of ſhots and ſhells be determined, without being acquainted with the laws of reſiſtance, and which cannot be known without the uſe of fluxions, nor the finding the curve deſcribed by the ſhot, which is one of the moſt intricate caſes? Again, the proper length and charges of pieces cannot be determined without the laws of motion in a reſiſting medium: it is true that experiments may be made for that purpoſe; but how far we may depend on them, without being confirmed by a proper theory, will appear hereafter.

A remarkable cuſtom has prevailed all over *Europe*, which is the making ſmaller calibers much longer in proportion than thoſe of a higher nature; imagining, I ſuppoſe, to increaſe thereby the velocity of the ſhot, without knowing that a piece may as well be too long as too ſhort: as long as this pernicious cuſtom prevails, no improvement can be made in artillery; for as a greater number of ſmall calibers are uſed than large, and the ſmall are thereby as heavy again as they need be, were their length of a juſt proportion.

Had it been known that every caliber has but one determined length and charge by which it will carry its ſhot farther than any other greater or leſs, and that it cannot exceed a determined velocity, let the ſhot be impelled by any force whatever, and that theſe velocities are always in proportion to the diameters of the ſhot, this practice would not have been followed. But as the demonſtrations of theſe principles depend on the method of fluxions, which would not have ſo well ſuited in a practical treatiſe as this, I was obliged to write a treatiſe, where every thing relating to artillery, not inſerted here, will be found.

To ſettle artillery upon a proper foundation, we ſhall relate all the moſt remarkable experiments made here and abroad, beginning with thoſe inſerted in *St. Remy*'s memoirs, volume i. page 114, which are ſaid to be the oldeſt upon record.

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It is eaſily perceived, that no dependance can be had on theſe experiments. For it is a plain contradiction, that the point blank ranges of a 24 and 16 pounders ſhould be longer than that of the 33 pounder; and that the random range of theſe laſt guns ſhould be no more than that of the 24 pounder. Again, the 16 pounder random range to be ſo much greater than the reſt.

Ranges in Paces.

Calib.	Point blank.	At random.
33	600	6000
24	800	6000
16	800	8000
12	450	5000
8	300	3000
4	150	1500

As neither the length and weight of pieces, nor the weight of the charges are mentioned, though the experiments were true, no uſeful inferences can be drawn from them.

Monſieur *du Metz*, lieutenant general, made in his time the following experiments on the ranges of guns, by which he found that the *French* pieces loaded with two thirds the weight of the ſhot, and thoſe of the new invention loaded with one third, ranged the ſame diſtances when elevated at an angle of 45 degrees.

Calib.	Ranges.
24	2250 Toiſes
16	2020
12	1870
8	1660
4	1520

As neither the length or the weight of the pieces are mentioned, nothing can be concluded from theſe experiments. It is ſurprizing that *St. Remy* did not mark the dates of theſe experiments, nor what the *French* pieces were at that time, as well as thoſe of the new invention. If I may venture to gueſs, their length were 10 feet, all except the 8 and 4 pounders, which were only 8 feet, according to the ſecond table hereafter; and thoſe that are called of the new invention had ſpherical chambers.

If

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If this be true, all that can be concluded is, that 10 feet is a better length for a 24 pounder than for any other caliber, when loaded with a weight of powder equal to the two thirds of their ſhot; but as no piece is loaded at preſent with that charge, theſe experiments can be of no uſe.

There are ſeveral tables of the lengths and weights of the *French* pieces uſed at different times not ſpecified, except the laſt of the preſent.

That which ſeems the oldeſt is the following, pag. 73, volume i.

This table ſhews how rude and imperfect the firſt trials of artillery were, and what enormous length the ſmaller calibers were made in thoſe times.

It is alſo to be obſerved, that the 24 pounder, tho' 13 feet long, weighed no more than 4300 lb. whereas the preſent of 10 feet weigh 5400 lb. If the former were found to be ſufficiently ſtrong, what could induce them to load them with ſo much metal now? All that can be ſaid is, that if experiments are made for a particular fancy only, and are not enquired into by the ſucceſſors, all the attempts an author can make for improvement are vain and uſeleſs to the public.

TABLE I.

Calib	Length.	Weight.
	Feet Inch.	
48	10 : 0	7200lb.
40	16 : 6	7000
32	22 : 0	7200
24	13 : 0	4300
20	16 : 0	7000
16	18 : 0	4200
12	11 : 0	4250
10	13 : 0	3850
8	15 : 0	3500
4	12 : 6	2500

In

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In the table facing page 207, vol. ii. are marked the following dimenſions.

This table ſhews, that the length and weight of pieces were better proportioned in that time than they were before: but that the length of the 24 and 16 pounders ſhould be the ſame as that of the 33; as likewiſe the 8 and 4 to be of the ſame length, ſhews the little reaſoning made uſe of in that time.

TABLE II.

Calib.	Length.	Weight.
33	10 : 0	6200lb.
24	10 : 0	5100
16	10 : 0	4100
12	10 : 0	3400
8	8 : 0	1950
4	8 : 0	1300

The laſt regulations that were made in 1732, and which are followed at preſent, may be ſeen in the next table. It is evident, that the lengths and weights were not deduced from any ſolid reaſon, but from the fancy of thoſe who are moſt at the head of that branch.

That the weight of theſe guns is greater than they need be, appears from our iron 24 pounders weighing no more than 4800, which is even too much, as will be ſhewn hereafter; and according to this proportion, the ſet of them contains 3250 lb. of metal more than the ſtrongeſt conſtruction requires.

TABLE III.

Calib.	Length.	Weight.
24	10 : 1.5	5400lb.
16	9 : 6	4200
12	9 : 0	3200
8	8 : 1	2100
4	6 : 9	1150

It muſt be obſerved, that the *French* reckon by the neat weight, and not by 112 pounds for a hundred weight, as we do; but it is ſhewn in page 11, that 100 *French* pounds weigh ſomething more than 114 of our

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our pounds; ſo that a *French* hundred neat weight is more than our hundred of 112 pounds.

We ſhall now come to the experiments made at home, or under the direction of *Engliſh* officers. The firſt on record that came to my knowledge are thoſe made by general *Armſtrong*, ſurveyor-general, in 1736, which are:

The length of theſe pieces are expreſſed in feet and inches, and the ranges in yards: out of a great many trials, three of the longeſt ranges of each piece are ſet down here. All theſe pieces were braſs 24 pounders, and all weighed nearly 5200, and were always loaded with two thirds of the ſhot's weight, that is, with 16 pounds.

Length.	Range.	Range.	Range.
10 : 6	2486	2614	2406
10 : 0	2570	2532	2436
9 : 6	2633	2560	2500
9 : 0	2796	2494	2563
8 : 6	2586	2490	2466
8 : 0	2438	2470	2453

The intent of theſe experiments was to find the beſt length for a battering piece, when loaded with the common charge then given; and that of 9 feet 6 inches was fixed upon as the beſt, though the firſt and laſt of the 9 feet ranges were the longeſt of thoſe in the ſame columns: this was owing, I ſuppoſe, to this length being more convenient for battering than that of 9 feet long.

If we examine ſtrictly into theſe experiments, it will be found, that no improvement can be made from them. For no two guns can be equally bored, and the leaſt difference may cauſe a conſiderable one in the ranges: nor no two vents can be pierced ſo as to come out at the ſame diſtance from the bottom of the bore, which is of the greateſt conſequence, as we ſhall prove from repeated experiments.

Length

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Length.	Number.	Elevation.	Ranges in Yards.	Powder.
11 Feet.	1	6 Degrees.	1780	9 Pounds of Powder.
	2		1750	
	3		1725	
	4		1725	
9 Feet.	5		2000	
	6		1830	
	7		1965	
	8		2018	
11 Feet.	9	7 ¼ Degrees.	1860	
	10		1935	
	11		1960	
	12		2048	
9 Feet.	13		2060	
	14		2165	
	15		2050	
	16		2272	
11 Feet.	17	10 Degrees.	2490	
	18		2395	
	19		2567	
	20		2670	
9 Feet.	21		2910	
	22		2780	
	23		2790	
	24		2577	
11 Feet.	25	12 Degrees.	3016	
	26		2720	
	27		2800	
	28		3000	
9 Feet.	29		2712	
	30		2910	
	31		2955	
	32		3070	

9 Feet.	11 Feet.			
	33	15 Degrees.	3185	9 Pounds of Powder.
	34		3095	
	35		3400	
	36		3185	
9 Feet.	37		3532	
	38		2940	
	39		3460	
	40		3725	
11 Feet.	41	10 Degrees.	2550	
	42		2377	10lb.
	43		2365	
	44		2575	
	45		2495	11lb.
	46		2375	
	47		2520	
	48		2605	12lb.
	49		2645	
	50		2730	10lb.
	51		2380	
	52		2445	
	53		2200	11lb.
	54		2780	
	55		2550	12lb.
	56	45 Degrees.	4160	9 Pounds.
	57		4135	
	58		4100	
	59		3970	
	60		4015	
	61		3980	
	62		3700	
	63		3960	10lb.
	64		3945	
	65		3785	11lb.
	66		3930	
	67		3802	12lb.

But

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But ſuppoſing all the pieces were exactly bored alike, and the vents placed the ſame, what other concluſion could be drawn from theſe experiments, than that the beſt length of a 24 pounder is 9 feet 6 inches when loaded with 16 pounds of powder? It is not probable, that if a leſs charge was uſed, as at preſent is the caſe, this length would be the beſt; neither can we draw any inferences from them in reſpect to the length of greater or ſmaller calibers.

It is not ſufficient to make experiments without any intention of their being uſeful towards the improvement of artillery in general, and ſuch as proper concluſions may be drawn from them; otherwiſe the greateſt uſe they can be of, is to determine ſome particular caſes only, which are by no means ſufficient.

The beſt and moſt uſeful experiments that have hitherto been made, are thoſe of general *Williamſon*'s, aſſiſted by major *Hiſlope*, and ſeveral other officers of artillery, which I ſhall inſert here, as taken from major *Hiſlope*'s account.

EXPERIMENTS made at *Mahon* in *Minorca* in 1745, with two iron 18 pounders, one of 11 feet long, which weighed 51 : 0 : 5; and the other of 9 feet weighed 39 : 1 : 3. They were fixed upon a rocky ground, and ſo contrived as to be elevated to any number of degrees.

Hence it appears, that when the pieces were loaded with 9 pounds of powder, the range was greater than when loaded with more or leſs.

Again, that the pieces of 9 feet long carried farther than thoſe of 11, in almoſt all the ſame circumſtances, though the firſt is lighter than the ſecond; which ſhews that the length of the ranges does not ſo much depend on the weight, as on a proper length, and on a proper charge.

The accuracy of theſe experiments is confirmed by the theory: for we have proved in our appendix, that the greateſt range an 18 pounder can have, when elevated to 45 degrees, cannot be quite equal to 4190 yards,

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yards, becauſe we have ſuppoſed ſuch a velocity as the ſhot cannot poſſibly have, but may continually approach it.

Now as the greateſt range in theſe experiments is 4160 yards, which differing only by 30 yards, the computed ones evidently prove the accuracy of theſe experiments; and it proves with no leſs certainty, that 9 pounds of powder communicated the greateſt velocity to the ſhot that it poſſibly could receive by any force whatever.

When thus experiments agree with a theory founded upon unexceptionable principles, there cannot remain the leaſt doubt of their certainty.

As 9 feet is nearly 21 diameter of an 18 pounder ſhot, and 9 pounds of powder half the weight of the ſhot; and it is preſumed that pieces, whoſe lengths and charges are proportional, will have their ranges likewiſe ſo; becauſe their greateſt velocities are proportional to the diameters of the ſhot, as we ſhall prove in the appendix: we may conclude with ſome degree of certainty, that if the length of a piece of any caliber be 21 diameters of its ſhot, and loaded with powder equal to half the weight of the ſhot, it will carry farther than any other of the ſame caliber, either longer or ſhorter, loaded with any charge whatever.

Thus we have at laſt determined that important queſtion in artillery ſought for ever ſince its invention; but to be entirely convinced of the truth of our determination, more experiments of this kind ſhould be made with various calibers; but care ſhould be taken that they may not be liable to any exception.

The moſt certain way of proceeding, in my opinion, would be, to caſt a gun of any caliber of 22 diameters of its ſhot long; to examine whether it is truly bored, and that the vent comes exactly out at the bottom of the bore; then let it be fired with various charges and elevations, till there is a ſufficient proof of its beſt charge; this being done, a part of the piece muſt be ſawed off the length of its diameter, and the firſt trials repeated

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repeated as before: and when the beſt charge and its range are aſcertained, the length of the piece muſt be diminiſhed again by the length of the diameter of its ſhot. Theſe trials being continued till the greateſt ranges diminiſhes, then the beſt length and charge will be aſcertained of that caliber; and thoſe of any other caliber may be found in the ſame manner. The only care to be taken in theſe experiments, is to mix well the powder, and to dry it in the ſun, that it may have always the ſame ſtrength as nearly as poſſible: another caution muſt be taken, which is, to make theſe experiments in clear and ſerene weather, and of the ſame heat, becauſe the powder will act more violently in a cold froſty morning than in hot weather, as we ſhall ſhew.

Though it is proper to know the beſt length and charge of a piece, yet in real ſervice their length depends moſtly on the uſe they are made of, according to the different circumſtances: thus ſhip guns ſhould be ſhort and light, ſo as to be eaſily houſed and loaded, becauſe the rammer handle is made of rope; in long pieces it muſt be bent, which requires great care to ram the powder and ſhot home; and when this is not done, the priming fires without the powder, which is always in cartridges; the ſailors thinking that the ſhot was diſcharged, load it again, and miſs firing as before. This has been found ſo for three times running, and when at laſt the powder in the firſt cartridge takes fire, often burſts the gun, and deſtroys the ſailors placed near to ſerve it; whereas when the guns are ſhort, the rammer handles may be made of wood in all ſmall calibers, and the ſervice become more expeditious. Beſides, ſhips now come ſo near to one another, that the ſhots are not required to go ſo far; provided it takes place it is ſufficient.

The only objection againſt light guns is, that if they recoil too much, they will be apt to tear their tackle; but it has been found by experience, that half the uſual charge is quite ſufficient, and perhaps leſs. If then the charge is diminiſhed, the weight of the gun may likewiſe

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wiſe be diminiſhed, without increaſing the recoil. This ſhould however be done with diſcretion, and not without proper trials; for hazards ſhould be avoided as much as poſſible.

Field pieces or battalion guns ſhould be ſhort and light, in order to be able to advance or retreat as faſt as the army; ſuch are thoſe we make uſe of at preſent, with very little alterations in the calibers above a 6 pounder.

Battering pieces, on the contrary, ſhould be of a proper length to enter into the embraſures, that by their blaſts they may not deſtroy them too ſoon, becauſe it cannot be prevented entirely; for which reaſon the gunners repair them every evening when it is dark.

With regard to garriſon pieces, their length ſhould be ſuch as that the ſhot may go fartheſt, becauſe in a ſiege they will oblige the beſiegers to open their trenches at a greater diſtance, which is generally without gun ſhot; and in a fort placed near a navigable river, or the ſea, they will reach the ſhips, when the ſhips cannot reach the fort.

For theſe reaſons we make in our new conſtructions the length of light field pieces 14 diameters of their ſhot, the ſhip guns 15 of thoſe diameters, and the battering as well as the garriſon pieces 21; whereby the 24 pounder for battering becomes 9 feet 8 inches long, which is 2 inches more than the uſual length. We might likewiſe uſe a 32 pounder, which, according to our conſtruction, page 52, would weigh but 5400, that is, only 200 more than our preſent braſs 24 pounder.

The intent of the following experiments, which I made in 1753 with two ſmall mortars, was to find the propereſt place of the vent, and the beſt figure of the chambers: their bore was three inches, and 7.5 long; one had a cylindric chamber of one inch diameter, and two long; the other a concave in the ſhape of an egg, with a ſmall cylindric entrance of half an inch diameter, and the inſide terminated by a ſharp edge. Both theſe chambers held an ounce of powder at firſt, but widened by

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by firing ſo as to hold an ounce and a quarter afterwards. Each had two vents, one in the middle, and the other at the bottom; I had a ſcrew to ſtop one when the other was uſed: the mortars weighed 36 pounds each, and the ſhells 2 pounds 7 ounces at a medium. We have not marked the angles of elevations, becauſe they were unneceſſary, only ſo far as that they were the ſame, when the lower and upper vents were compared.

Pdr.	Vent	Cylind.	Concave	
One Ounce.	Middle.	630 630 600 550 560	750 730 686 722	Loaded with the common ſhooting powder. Weather cool in the morning, and ſultry afterwards.
	Lower.	806 900		
	Middle	800 756 864	889 875 877	With common ordnance powder. Weather warm and windy.
1¼ Ounces.	Lower.	1100 1023 1003 1020 1020	1194 1088 1121 1122 1200	With the beſt ordnance powder. Weather warm and windy.
		Ranges in Yards.	Ranges in Yards.	

Colonel *Deſaguliers* and myſelf made ſeveral other experiments, together with a mortar of the ſame ſize that had ſeveral ſhifting chambers. The ſubſtance of what was moſt remarkable in them are as follows:

A narrow cylindric chamber of about four inches long holding 12 grains of powder, being loaded with 6 grains by means of a thin cartridge: when the powder was placed cloſe to the ſhell, ſo as the lower part of the

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chamber was empty, and fired by means of a quick match introduced through the vent; and after this, it was loaded again with the ſame charge placed at the bottom of the chamber, and the empty ſpace between the ſhell and the powder; the ſhell went near twice the diſtance in the firſt experiment that it did in the ſecond, and when the powder was placed in the middle of the chamber at an equal diſtance from the bottom and the ſhell, the diſtance or range was a mean between the two former. Theſe experiments were frequently repeated, and the ranges in the firſt caſe were always nearly double thoſe in the ſecond. From what cauſe it may proceed that the ſame quantity of powder, placed in the ſame ſpace, ſhould produce ſuch various effects, is not in my power to conjecture.

The ſame mortar being loaded with the ſame quantity of looſe powder, I put a little piece of writing paper upon it, by which the ſhell went much farther than when loaded with the ſame quantity of powder without paper.

Three cylindric ſhifting chambers of different lengths holding the ſame quantity of powder, produced the ſame range when full; but when they were not quite filled, the longeſt produced the greateſt range.

Two chambers in the form of a fruſtum of a cone, the largeſt baſe was at the bottom in one, and the ſmalleſt of the other; the firſt carried the ſhell farther than the ſecond.

The colonel tried two experiments more; the one between grained and mealed powder; and they were both found to be of an equal ſtrength: and the other he put a ſmall phial filled with water into the chamber amongſt the powder, and found its ſtrength conſiderably increaſed; that is, the ſhell went farther with the water than without it. The colonel tried likewiſe a cylindric chamber of about four inches long, with four vents, one at the bottom, one at the upper end, and two in the

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the middle, all four at an equal diſtance from each other, ſo that when one was uſed, the others were ſtopped by ſcrews; and he found that the loweſt carried the ſhell fartheſt, and the ranges of the others diminiſhed in proportion as they were diſtant from the bottom.

Many uſeful obſervations may be made on theſe experiments. Firſt, that the vent placed near the bottom of the chamber is more advantageous than any where elſe; though this has been found ſo in mortars, we are not certain that it is the ſame in guns, which ſhould therefore be tried; and if it be found the ſame, the query is, whether the bottom of the bore ſhould not be flat, inſtead of roundiſh, as is the cuſtom, or to pierce the vent from the breech moulding, as colonel *Weideman* did, or elſe as the *French* do in ſome of their mortars, with a ſmall cup at the end of the chamber to receive the vent. From hence it appears how inaccurate experiments have hitherto been made, and how neceſſary it is to make new with all the neceſſary precautions, in order to improve artillery, and to bring it to perfection.

Before theſe experiments were made, it was imagined, that when the vent is in the middle of the chamber the range would be the greateſt, becauſe if a tube filled with powder was lighted in the middle, the powder would be burnt in half the time it would if lighted at one end, and it was ſuppoſed that the greater quantity burnt before the ſhot was ſenſibly moved from its place, the greater force it would receive; but notwithſtanding this plauſible reaſon, experiments have evinced the contrary.

The next obſervation to be made is, that the concave chamber is preferable to the cylindric, and this to any other; which has not hitherto been conſidered: the *Spaniards* make theirs ſpheric, the *French* in the ſhape of a pear; and we conical. The various opinions authors and artilleriſts have concerning the figure of chambers are very extraordinary. The chevalier *Belidor* eſteems the conical the beſt; but his reaſoning concerning the pro-

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perties of different chambers in page xxiv. of his *Bombardier François*, are so very weak and inconsistent, that it is needless to answer them: how so great a man as he is in all other respects could descend to such vulgar errors is inconceivable.

Mr. *Robins*, in page 41, old edit. pretends, that the figure of a chamber has no effect upon the action of powder, without shewing the least reason for his assertion. Count *Bukeburg* will have a parabolic form, imagining, that if the fire was introduced to the focus, the rays of lighted powder would, by the nature of the figure, reflect into parallel direction in the same manner as the rays of light: supposing this was true, the shell would not receive a greater force by it, because a fluid acts always in a perpendicular direction to the surface it strikes; thus in a globe the directions of the fluid tend all to the center, as we shall prove in the fifth theorem; and when all the forces are reduced to the direction of the shell, it is that force reunited into one direction that produces the real effect, and not the partial ones. This not only refutes what his lordship said, but likewise *Belidor* and *Robins*, as having all split upon the same rock. It is not the inward figure of the chamber, but its entrance, which produces the effect; because the smaller it is, the nearer it reduces the effect into the direction of the shell. This is likewise proved by the practice of making sky-rockets, which being choaked at the end, by which it confines the force of explosion into a narrow stream, and increases its violence so as to make the rockets rise so high as they do; whereas if the opening was not confined, they would scarcely rise at all. The notion that a concave chamber with a narrow neck shakes the mortar violently without increasing the force of explosion, or the range, is so inconsistent with the laws of motion, that it merits not the least attention.

It is the general opinion of the artillery officers, that a mortar or gun carries farther when it is warm by much firing than when cold, or in the heat of the day than in the

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the morning. The conſtant practice by ſea and land is, that when the guns are much heated to diminiſh their charges, from the notion that they carry them much farther; which is a miſtake. For when guns are much heated, they are liable to be ſpoiled; and it is prudent to leſſen their charges in that caſe. For it appears from my firſt four experiments made in the cool of the morning, that the ranges were greater than thoſe when the weather grew warm. The chevalier *Belidor* made ſeveral experiments for that purpoſe, which I have ſeen, and which are mentioned in general only in his *Bombardier*, page xxxviii; but the particulars are as follows: ſeveral mortars were fired in the cool of the morning; the ſame trials were repeated in the middle of the day when it was very hot, and the ranges in the morning were always greater than thoſe in the heat of the day: but as this was not ſufficiently ſatisfactory, the chamber of a mortar was heated with lighted charcoals as hot as could be without endangering the powder from taking fire; the range in this ſtate of heat was much ſhorter than when the mortar was quite cold. It is true that heat will dry the powder, and gives it a greater force, if it remains a certain time in the chamber, which is not the caſe in briſk firing; and dried powder is better than when it is damp; yet the elaſticity of the air is much increaſed by cold, and relaxed by heat; I mean from the ſtate of the atmoſphere.

Having ſaid every thing neceſſary in reſpect to the length of guns, we are now to conſider their thickneſs or ſtrength of their ſeveral parts, which ſhould be proportional to the efforts of fired powder; but its abſolute force cannot be determined otherwiſe than by experiments. The weight of the guns depends on the charge of powder, and on their length; and though the charge has been leſſened from that given formerly, yet the thickneſs of metal remains in general the ſame; nor have the experiments with light guns mentioned before,

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prevailed as yet in diminiſhing the weights of larger calibers.

I had two braſs 12 pounders caſt for admiral *Keppel*, according to the conſtruction in page 54; they weighed 13 : 1 : 0, which ſtood the full ordnance proof; the old weigh 29 : 1 : 0.

I had alſo ſeveral eighteen braſs pounders caſt for the *India* company; ſome of them were lately proved at *Woolwich* with fifteen pounds of powder, though the charge in ſervice ſhould not exceed ſix pounds: they weigh 2400, and are 9 feet long: a 24 pounder would in the ſame proportion weigh 3200, and their length 9 feet 8 inches. I look upon this proportion to be ſufficiently ſtrong for braſs battering pieces, though much lighter than the preſent; even a 32 pounder of that length would weigh only 4200, and in my opinion make better battering pieces; becauſe the largeſt ſhot makes a breach ſooner than a ſmaller, and the ancients made uſe of 48 pounders for that purpoſe; but on account of their unweildineſs they were reduced to 24 pounders, not that they were better, but more manageable. That theſe guns are ſufficiently ſtrong appears not only from their proof, nor that they weigh twice as much as thoſe of the light nature, but likewiſe from ſome old 32 iron pounders caſt in king *Charles* the ſecond's time; ſome of them remain ſerviceable to this day, and they weighed 4200 only.

The firſt caſt guns were made of what is called gun metal, and this metal continued for a great while before caſt iron was uſed; but in time, as artillery became more in uſe, the number of cannon became very great, and to leſſen the expence iron guns were invented; but the opinion of their being liable to burſt when much heated by firing, was the cauſe of making them heavier than the braſs; and as ſome did burſt in effect, either through wrong management, or the unſkilfulneſs of ſome founders, this notion has prevented the more general uſe that might be made of them to this day. But for what reaſon

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reaſon we make them much heavier now than in king *Charles*'s time cannot be accounted for; for the preſent 32 and 42 pounders weigh 54 and 55 or 56 hundreds; whereas they weighed formerly only 4200 and 5200. This cannot be owing to better ore, or to more ſkilful founders; becauſe I have ſeen iron caſt by the *Carron* company that could not be broke by any means, but would flatten and tear like braſs. I had two iron three pounders caſt by that company for lord *Egmont* that weighed 3 : 3 : 0 each, which ſtood the full ordnance proof with three pounds of powder; whereas their charge in ſervice ſhould never be more than one fourth, or at moſt one third of that quantity. I had ſince two ſix and two twelve pounders caſt by the ſame company for the *Portugueſe* ſervice; the firſt weighing 7 : 3 : 0, and the others 15 : 2 : 0; and though they are not yet proved, I will anſwer for their ſtrength. The old 6 pounders weigh 17 : 1 : 0, and the 12 pounders 32 : 2 : 0.

That iron pieces are preferable to braſs evidently appears from the experience we had in the laſt war; for at *Belleiſle* the braſs guns were ſoon rendered uſeleſs, and iron ſhip guns were uſed to finiſh the ſiege. I have been aſſured by ſeveral artillery officers, that in all the ſieges we made in the laſt war, they were obliged to uſe iron guns, becauſe the braſs did never ſtand great firing, though they weigh 400 more than the iron.

This is eaſily accounted for, becauſe gun metal is a compoſition of copper and tin; the copper requires a red heat to melt, and tin only a common fire; ſo that when the gun is heated by much firing, the tin melts, and the copper alone remains to ſupport the force of exploſion; by which the muzzle droops, and the vent widens ſometimes to that degree, as a man's fiſt may go in it. To make the vent more durable they put in a piece of copper to grain it, as it is called. This grain is fixed into the mould before the melted metal is let in to make them unite together; but as copper is ſofter than gun metal, inſtead of making the vent more

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durable, as it is imagined, it rather weakens it in my opinion. If a ſteel grain was put in, provided it can be united with the metal, there is no doubt but it would be better than any other metal; for it has been found by experience, that a new vent of iron being made, it was ſcarcely ever ſpoiled afterwards. The *French* had a gun with an iron vent at *Belleiſle*, which was found after the ſiege to be the only one that ſtood out the ſiege without being ſpoiled. To make a compoſition of gun metal of a durable ſubſtance, the ingredients ſhould be ſuch as require the ſame degree of heat to melt; but no ſuch metals have as yet been diſcovered. It is true, that ſome *Saxons* pretend to have that ſecret; but as they have not yet made any guns of it, no dependance can be made on it.

As good iron caſt from virgin ore has all the quality that can be deſired in gun metal, and not one burſt all this war that I heard of, what occaſion is there for any other? and there is ſuch a plenty of it every where, eſpecially in *England*, and the founders are ſo expert in their buſineſs at preſent, that they can make it more or leſs malleable, as they pleaſe; beſides, the expence is ſo much leſs, as 9 or 10 to one; which one would think ſhould be a ſufficient motive to uſe no other. Although the artillery officers agree, that iron battering pieces are preferable to braſs, yet to make field pieces of iron they by no means approve of, becauſe they ſay it would be too dangerous to ſtand by them in time of action; but what ſhould prevent a proper trial to be made? And if it does not ſucceed, the expence would be inconſiderable; and if it does, as I do not doubt it will, what a prodigious expence would be ſaved.

I would adviſe to have two ſix pounders caſt of the ſame weight as the braſs, and proved in the ſame manner; then fire them three hundred rounds as quick as they can, with a pound and a quarter of powder, in the ſame manner as the braſs were tried; and if they ſtand ſuch a trial, let the officers then judge whether there can be

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be any danger in using them. We are not to judge rashly in a matter of so great importance as this, without a full and sufficient proof. It is not the opinion of a few persons we are to judge by, but by matter of fact. I may possibly be mistaken, though I think to have sufficient proofs of what I assert; and therefore recommend proper trials to be absolutely certain.

As we propose chambers to be made in all calibers from an 18 pounder upwards, it will not be improper to shew here their advantage, first from experiments, and afterwards from theory. General *Williamson* and the rest of the artillery officers made likewise several experiments with shells from a bomb vessel in the harbour of *Mahon* in 1746. Of which I shall only insert the range of the fifth, which was 4570 yards; the mortar was loaded with 35 lb and 10 ounces, the shell weighed two hundred or 224 pounds, and the angle of elevation 45 degrees; and the range of the seventeenth experiment with a ten inch mortar was 3787 yards; the shell weighed 97 lb. and the mortar loaded with 12 pounds of powder. Now the charge of the first mortar being about 5.6 parts of the weight of the shell, produced a greater range than the 18 pounder gun loaded with half the weight of the shot; the second mortar was loaded with no more than an eighth part of the shell's weight, and yet its range differed but 373 yards from that of the gun. This great difference between the forces of powder, when it was confined in a chamber, and in a gun without a chamber, can arise from no other cause, than that the direction of its force is nearer to that of the shell than it is to that of the shot. It is true, that the resistance of the air is less on the shell than on the shot; but, on the other hand, the bore of the mortar is so short, and so wide in comparison to the width of the chamber, that the explosion of the powder can only act upon the shell before it is sensibly moved from its place; instead of which it acts upon the shot till it leaves the gun. All this being considered, the advantage

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tage of chambers in guns, as well as in mortars, will be found to be very conſiderable.

We ſhall prove this likewiſe by theory hereafter in theorem the vth.

Though we have ſhewn that the theory of powder is as yet defective in many reſpects for want of a ſufficient number of good experiments, thoſe which have hitherto been made were with too ſmall quantities, as can by no means be depended upon; ſince the ſmalleſt error in a few grains becomes very conſiderable in the charges of artillery pieces; neither do we know the time of the degrees of inflammation. All that can be done, is to ſuppoſe that it fires all at the firſt inſtant, and proceed upon this ſuppoſition, though erroneous, till ſuch time that the law of inflammation has been diſcovered.

THEORY of POWDER.

THEOREM I.

The exploſion of fired powder produces a permanent elaſtic fluid, and forms a ſphere, if not prevented by any external obſtacle.

AUTHORS agree, and experience ſhews, that fired powder produces an elaſtic fluid; and if it be fired under an exhauſted receiver, the mercurial gage deſcends; and though it riſes again when the heat is abated, yet it remains always below its common ſtandard; which plainly ſhews, that the fluid produced by fired powder is elaſtic and permanent.

Again, if a ſmall quantity of powder be fired on a table, its flame riſes in the form of a ſemi-ſphere; and in whatever veſſel powder is confined, the exploſion will always burſt it in the weakeſt part, if the elaſtic force be

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be ſufficient. Conſequently fired powder acts on every ſide alike; which could not happen, unleſs the exploſion was ſpherical.

REMARK.

Though authors agree, that powder produces an elaſtic fluid when fired, yet they differ in the manner of it. Moſt of them are of opinion, that powder is only condenſed air, which being heated by the exploſion, as well as the natural air contained between the interſtices of the grains, produces this elaſtic fluid. Others affirm, that the air contained in powder exiſts in its natural ſtate; which being heated expands itſelf, and produces the exploſion. But this is contradicted by the above-cited experiment: for when the heat in the receiver is abated, the mercurial gage ſhould, according to this ſuppoſition, riſe again to the ſame height as it was before; which is contrary to experience.

Sir *Iſaac Newton* ſays, in his *Optics*, Query 10, that if ſalt of tartar be mixed with powder, and that mixture be heated till it takes fire, the exploſion will be more violent and quick than that of powder alone; which can proceed from no other cauſe, than the action of the vapour of the powder upon the ſalt of tartar, whereby that ſalt is rarefied; and therefore the exploſion of powder ariſes from the violent action, whereby all the mixture being quickly and vehemently heated, is rarefied and converted into fume and vapour; which vapour, by the violence of that action becoming ſo hot as to ſhine, appears in the form of flame. Thus far Sir *Iſaac Newton*.

But whether the elaſtic force of powder be owing to the expanſion of air, or to ſome other fluid produced by the ingredients of which it is made, is not material in reſpect to what follows; it being ſufficient for our purpoſe, that the force produced thereby acts chiefly according to the ſame law as all other elaſtic fluids; which it will be proved to do by experiments hereafter.

THEOREM

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THEOREM II.

The denſities of the ſame quantity of an elaſtic fluid, contained in different capacities, are as theſe capacities inverſely.

For the ſame quantity of matter being reduced to half the bulk, will have its parts twice nearer each other; if it be reduced to one third or one fourth of the bulk, the parts will be three or four times cloſer to each other; and whatever the bulk is reduced to, the parts will always be cloſer to each other in the ſame proportion. And ſince the denſity of matter conſiſts in the cloſeneſs of the parts, it is evident that the denſity increaſes as the bulks diminiſh; conſequently, the denſities of the ſame quantity of an elaſtic fluid, contained in different capacities, are as theſe capacities inverſely.

COR. I.

Hence it follows, that the denſities of different quantities of the ſame elaſtic fluid, contained in the ſame or equal capacities, are as theſe quantities. For if twice the quantity be contained in the ſame capacity, the denſity will be double; if three or four times the quantity be contained in the ſame capacity, the denſity will be triple or quadruple; and therefore, in general, whatever the ratio is between the quantities contained in the ſame or equal capacities, that of the denſities will always be the ſame.

COR. II.

Hence the denſities of different quantities of the ſame elaſtic fluid, contained in different capacities, are as the quantities directly, and the capacities inverſely. For becauſe the denſities of the ſame quantity of an elaſtic fluid,

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fluid, contained in different capacities, are as these capacities inversely, by Theorem II. and the denſities of different quantities of the ſame fluid, contained in the ſame or equal capacities, are as theſe quantities directly by Cor. I. it is evident, that if the quantities are different, as well as the capacities, the denſities will be as the quantities directly, and the capacities inverſely.

THEOREM III.

The intenſity of heat produced by the exploſion of fired powder, will be as the denſity of the fluid.

For the heats of the ſame quantity of powder, fired in different capacities, will be as theſe capacities inverſely; and the heats of different quantities, fired in the ſame or equal capacities, are as theſe quantities directly. Therefore the intenſity of heat produced by different quantities of fired powder in different capacities, is as the quantities directly, and the capacities inverſely; or as the denſities by the laſt Corollary.

THEOREM IV.

The elaſtic force produced by an exploſion of fired powder, is in the compound ratio of the denſity of the fluid, and the intenſity of heat.

For the elaſtic force of condenſed air is as the force of compreſſion, and the force of compreſſion is as the denſity; and ſince the elaſtic force is alſo increaſed by heat, it is manifeſt, that the elaſtic force is in the compound ratio of the denſity of the fluid, and the intenſity of heat.

This may likewiſe be proved as follows: ſince every particle of the fluid has the ſame degree of heat, and the total force of the exploſion is equal to the ſum of the forces of all the parts; the elaſtic force of the exploſion

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ploſion is therefore in the compound ratio of the heat of one particle, and the ſum of all the particles, or, which is the ſame, the denſity of the fluid. Conſequently the elaſtic force, produced by the exploſion of fired powder, is in the compound ratio of the denſity of the fluid, and the intenſity of heat.

Remark.

Mr. *Robins* ſuppoſes the elaſtic force, produced by the exploſion of fired powder, to be as the denſity of the fluid, which is the caſe of condenſed air void of heat; and therefore he ſuppoſes the increaſe of force, produced by heat, to be conſtant, in his propoſition; but finding afterwards that the force increaſed by heat, he ſays, we have hitherto ſuppoſed powder, when fired, to be equally hot with iron, at the beginning of its white heat; but we have obſerved, that it varies according to the quantity of powder fired together. The flame therefore may have all the different degrees, from that of a languid red heat, to the heat ſufficient for the vitrification of metals; which agrees exactly with what has been ſaid in the laſt Theorem. That heat increaſes greatly the elaſticity of air, is known by heating an empty bottle, well corked, in boiling water; for it will either drive the cork out, or elſe burſt the bottle. It is likewiſe well known, that the ſteam of boiling water produces a great elaſtic force, and perhaps more than fired powder; although cold water ſeems to be intirely void of elaſticity, ſince it cannot be compreſſed by any force we know of. Hence it ſeems as if cold water was in its denſeſt ſtate; and it appears very probable, that the denſity of air has its limit, beyond which it never can be reduced.

Cor. I.

Since the intenſity of heat is as the denſity of the fluid, by Theor. III. and the elaſtic force of fired powder

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der is in the compound ratio of the denſity of the fluid, and the intenſity of heat, the elaſtic force of fired powder is therefore in a duplicate ratio of the denſity; and, conſequently, by Cor. II. of Theor. II. the elaſtic force of fired powder is in the duplicate ratio of the quantity of powder directly, and the duplicate ratio of the capacities inverſely.

Cor. II.

Hence, if the quantities of powder are in the ſame ratio as the capacities in which they are contained, the forces of exploſion will be equal.

For ſince theſe forces are in the duplicate ratios of the quantities of powder directly, and the duplicate ratio of the capacities inverſely; the ſingle ratios being equal by ſuppoſition, the duplicate will likewiſe be equal.

Cor. III.

By a known property of fluids in general, the preſſure againſt any ſurface is in the compound ratio of the impreſſing force, and the ſurface preſſed; and ſince, of all equal ſolids, the ſphere has the leaſt ſurface, it is evident, that of all capacities which contain the ſame quantity of powder, the ſpheric is the ſtrongeſt, or, which is the ſame, is the leaſt preſſed.

Cor. IV.

Hence, the forces againſt ſpheric ſhells, filled with quantities of powder proportional to their capacities, are to each other as the ſquares of their radii; for the forces of exploſion being equal by Cor. II. the forces againſt theſe ſhells will be as the ſurfaces preſſed; and they being as the ſquares of the radii, the forces impreſſed will be in the ſame ratio of the ſquares of the radii. Conſequently, if the thickneſs of ſhells are proportional

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portional to their radii, they will be equally ſtrong, ſince their thickneſs will be to each other as the ſquares of the radii, and conſequently as the impreſſing forces.

Cor. V.

It is alſo manifeſt, that the forces againſt the concave part of the cylindric ſurfaces, filled with proportionable quantities of powder, are as theſe ſurfaces: for the forces of exploſion are equal in this caſe, by Cor. II. and therefore the impreſſing forces are as the ſurfaces preſſed. Now becauſe cylindric ſurfaces are in the compound ratio of their radii and their axes; if the axes are equal, the forces are as their radii; if the radii are equal, as their axes; and if they are ſimilar, as the ſquares of the radii or axes.

Remark.

When pieces of artillery are loaded with charges proportional to the weights of their ſhots, the axes of the charges are proportional to their radii; and as they are equally preſſed by the elaſtic force of powder, as far as the charge reaches, their outward ſurface ſhould be ſo far parallel to their inner one, and the thickneſs of the metal made proportional to the radii of their baſes; or becauſe the diameters of the bores are proportional to the diameters of the ſhots, and from thence to the mouth, the outward figure ſhould be that deſcribed by the rotation of a cubic hyperbola about one of its aſſymtotes, which is placed in the axis of the bore: this appears from what has been ſaid in Cor. I. after Theor. IV. But becauſe of the action of the ſhot againſt the inſide of the piece, the thickneſs of metal muſt be ſomewhat more towards the muzzle than what this figure makes it.

Before the foregoing Theory can be applied to any particular example, it is neceſſary to find the ratio be-

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tween the preſſure of the atmoſphere and the elaſtic force of powder, which is very difficult, becauſe authors diſagree very much in their experiments on that head.

For Mr. *Robins* ſays, that the air contained in powder is but 244 times denſer than that we breathe; and that its elaſticity cannot be increaſed above five times by the heat of the exploſion; and from thence he concludes, that the elaſtic force of fired powder is about 1000 times greater than the preſſure of the atmoſphere. The late Mr. *Haukſbee* aſſured me, that he found, by ſeveral experiments, the flame of powder to occupy about 5000 times the ſpace of the powder unfired. Mr. *Belidor* ſays, that, by ſome experiments he made, he found that ſpace to be about 4000 times increaſed, and that the ſame thing had been found by Mr. *Amonton*. Mr. *Bigot de Morogues* ſays, in page 65, that he found that ſpace to be from 4 to 4500 times; and laſtly, *Daniel Bernoullie* found it to be from 4 to 6000 *.

It is certain that theſe experiments are attended with great difficulties, on account of the quickneſs with which the powder fires, and the flame diſappears. Another difficulty ariſes from the inequality of the preſſure of the atmoſphere, as well as from the different ſtrength of powder; and therefore it is impoſſible to arrive at any tolerable degree of exactneſs, notwithſtanding all the precautions that can poſſibly be taken in making the experiments: ſo all that can be expected will be to take ſuch a number as agrees neareſt with the experiments made on the velocities of ſhots, which is that of Mr. *Belidor*'s, as being a mean between the greateſt and leaſt of theſe ſeveral experiments.

* Mr. *Boyle* ſays, that the greateſt denſity of air is to the greateſt rarefaction, as unity to 520,000.

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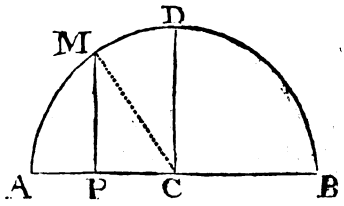
THEOREM V.



The force of an elaſtic fluid againſt any part of a ſpheric ſurface deſcribed by the arc DM *about the radius* CD *as an axis, perpendicular to the diameter* AB, *is to the abſolute force, as the ſolid deſcribed by the ſegment* PMDC *terminated by the ſine* PM *of that arc, is to the cylinder of the ſame baſe and altitude; and the force againſt the ſemi-ſphere is to the total force, as the ſemi-ſphere to the circumſcribed cylinder.*

Draw the radius CM; then, by the nature of fluids, the ſurface is preſſed in a direction perpendicular to every point; whence the abſolute force in the direction CM is to the force impreſſed at the point M, in the direction PM, as CM is to CP; and as this happens in reſpect to every point in the arc MD, the force impreſſed on the arc MD, will be to the abſolute force as the area PMDC is to the rectangle made by CP and CD: conſequently the force againſt the ſurface deſcribed by the arc MD about the axis CD, is to the abſolute force as the ſolid deſcribed by the ſegment PMDC in that rotation to the cylinder, deſcribed by the rectangle PC and CD; and the force againſt the ſemi-ſphere is to the abſolute force, as the ſemi-ſpehre is to its circumſcribed cylinder.

Mr. *Robins* and Mr. *Morogues* have ſuppoſed, that the force againſt the ſemi-ſphere was equal to that againſt the circle AB of the baſe: but they did not conſider, that the directions of the forces againſt the different parts of the ſphere were oblique to the direction CD, in which the ſphere is ſuppoſed to move; and therefore the total force muſt be leis than the abſolute force.

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This Theorem agrees exactly with Sir *Isaac Newton*'s prop. 35, book ii.

Cor. I.

Since the ſphere is the two thirds of its circumſcribed cylinder, it follows that the ball is acted upon by the two thirds of the abſolute force of the powder.

Example I.

If we ſuppoſe C P to be a third part of the radius C A, it will be found by geometry that the cylinder, whoſe radius of the baſe is C P, and altitude C D, is to the ſolid deſcribed by the ſpace C P M D about the axis C D; or the total force of the powder is to that part which acts upon the ſurface deſcribed by the arc M D, as 900 to 875: and ſince the ſemi-ſphere is acted upon by the two thirds of the total force of the powder, and if the quantity be the ſame in both cauſes, the force of exploſion upon the ſphere will be to the part which acts upon the ſurface deſcribed by M D, as 600 to 875; which ſhews that the force againſt the ſurface is only 25 parts leſs than the abſolute force 900: whereas the force againſt the ſemi-ſphere is but 600, the two thirds of the abſolute force 900.

Example II.

If C P be one half of the radius C A, then it will be found in the ſame manner as before, that the circumſcribed cylinder is to the ſolid deſcribed by the ſpace C P M D; or the total force of the powder is to the part acting upon the ſurface deſcribed by the arc M D, as 900 to 841; and the force acting upon the ſphere acting upon this ſolid, as 600 to 841.

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COR. II.

Hence it is manifeſt that chambers, whoſe diameters are but one third of the diameter of the bore, are more advantageous than thoſe whoſe diameters are one half, as they are made at preſent in our mortars; and if they were ſtill leſs, they would be better; which however may have its limits. This agrees exactly with ſeveral experiments made for that purpoſe: for Mr. *Hawkſbee* tried ſeveral times a little mortar, which had three ſhifting chambers of the ſame capacity, and always found that the chambers which were narroweſt carried the ſhell fartheſt.

As the firſt part of artillery was printed before the 18 braſs pounders have been proved, and the general conſtruction of theſe pieces appears to be properly adapted to braſs guns for the land ſervice, I ſhall inſert it here, in order to ſhew how much the metal might be diminiſhed.

General conſtruction of braſs cannon for the land ſervice.

Let the length A B, ſee plate I, be 21 diameters of its ſhot, the thickneſs of the metal at the breech and vent 18.5 parts, and at the mouth 9; the reſt of the conſtruction may be the ſame as that given in page 46.

Weight.

Weight and dimenſions of braſs guns for land ſervice.

It muſt be obſerved, that we made the lengths of the 24, 32, and 42 pounders the ſame, being ſufficient for battering pieces, and reduces the weight of the two laſt conſiderably; that theſe pieces are ſufficiently ſtrong appears from the old iron 32 and 42 pounders caſt in king *Charles* the ſecond's time, which weighed no more. But it muſt be remembered, that the charges of theſe pieces ſhould never exceed one third of their ſhot's weight, becauſe that charge has been found ſufficient by experiments in all battering pieces.

Calib.	Length.	Weight.
6	6 : 1	8 : 0 : 4
9	7 : 0	12 : 0 : 6
12	7 : 8	16 : 0 : 8
18	9 : 0	24 : 0 : 12
24	9 : 8	32 : 0 : 16
32	9 : 8	42 : 0 : 20
42	9 : 8	52 : 0 : 24

We have inſerted this table of the dimenſions of iron field pieces, in order to ſhew how they may be conſtructed, in caſe it ſhould be thought proper to make trial of their ſtrength. Their length is 14 diameters of the ſhot, the thickneſs of metal at the breech and vent 18 parts, and 9 at the mouth; the reſt of the conſtruction is the ſame as that of the light braſs field pieces.

Iron Field Pieces.

Calib.	Length.	Weight.
3	3 : 3	2 : 1 : 0
6	4 : 1	4 : 2 : 0
9	4 : 8	6 : 3 : 0
12	5 : 1	9 : 0 : 0
18	5 : 10	13 : 2 : 0
24	6 : 5	18 : 2 : 0

The proof of theſe pieces ſhould be made with one half of the ſhot's weight of powder,

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powder, and their charge in ſervice one fourth, which is the ſame as thoſe of braſs.

If theſe pieces are caſt from good virgin ore by a ſkilful founder, ſuch as the *Carron* company, and ſome others, without mixing any pig iron, there cannot be the leaſt doubt but they will be as uſeful, and laſt longer than the light braſs; becauſe their vents ſcarcely ever ſpoil, and the pieces never bend at the neck.

The reader may perhaps be glad to know the greateſt velocities that ſhot can have, and their greateſt ranges, which often have been ſought for by moſt artilleriſts, but they could never agree; for which reaſon we ſhall inſert them in the following table.

Shot	Velocities.	Ranges.
3	615.7	2326
6	691.3	2932
9	739.0	3352
12	775.3	3688
18	826.5	4191
24	866.8	4610
32	912.9	5113
42	955.5	5602
48	976.4	5849

The firſt column contains the weight of the ſhot, the ſecond the number of feet moved over uniformly, in a ſecond by the greateſt velocity; and the third the greateſt random ranges which theſe ſhots can poſſibly have, let the charges be ever ſo great.

This ſhews that ſmall calibers can never go ſo far as greater, and contradicts the common practice of making ſmall calibers longer in proportion, in order to go farther.

A ten inch ſhell may go to 5384 yards at an elevation of 45 degrees, and a thirteen to 7041 yards at the ſame degree of elevation; which is upwards of four miles. Again, the greateſt velocity a leaden bullet of three quarters of an inch diameter can poſſibly have, is at the rate of 395 feet a ſecond, when uniformly continued.

The

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The demonstration of these velocities and ranges is given in the appendix. Mr. *Robins* thinks to prove, in his seventh problem, that the velocity of the foregoing leaden bullet is 1668 feet in a second, which is more than four times greater than that above; and what is more extraordinary, he pretends to have found the same velocity by experiments. As he seems to build his theory upon Sir *Isaac Newton*'s principles, had he read the 40th proposition, book ii. he must have been convinced of his mistake; and from over-rating the velocities, the resistance of bodies moving in the air is, according to his computation, above twenty-four times too great in a 24 pounder.

Height. Distance.			Height. Distance.		
Yds.	Yards	Miles	Yds.	Yards	Miles
1	3735	2. 12	26	19048	10. 82
2	5278	3. 00	27	19410	11. 03
3	6470	3. 67	28	19767	11. 23
4	7470	4. 24	29	20107	11. 42
5	8353	4. 74	30	20460	11. 62
6	9150	5. 20	31	20800	11. 82
7	9863	5. 60	32	21133	12. 00
8	10566	6. 00	33	21459	12. 20
9	11206	6. 36	34	21780	12. 38
10	11800	6. 70	35	22100	12. 55
11	12390	7. 04	36	22413	12. 73
12	12940	7. 35	37	22720	12. 91
13	13468	7. 65	38	22895	12. 97
14	13977	7. 94	39	23329	13. 20
15	14468	8. 22	40	23631	13. 40
16	14942	8. 49	41	23919	13. 59
17	15402	8. 75	42	24209	13. 75
18	15850	9. 00	43	24500	13. 92
19	16283	9. 25	44	24780	14. 08
20	16706	9. 49	45	25059	14. 24
21	17118	9. 72	46	25336	14. 40
22	17521	9. 95	47	25610	14. 55
23	17915	10. 18	48	25880	14. 70
24	18300	10. 40	49	26148	14. 85
25	18678	10. 61	50	26414	15. 00

As

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As the diſtance a ſhip may be ſeen at ſea is eſteemed uſeful, we have given them from one yard high to 50, from the ſurface of the ſea, and the reſpective diſtances in yards and miles: they are deduced from the roundneſs of the ſeas ſurface, according to the prob. in art. 411, of our treatiſe of mathematics: the mean diameter of the earth being 6548856 *French* toiſes, according to our determination; which being reduced into *Engliſh* yards, gives 7.1447018 for its logarithm; to which adding continually the logarithm of the height, gives the logarithm of the ſquare of the diſtances in yards; and the diſtances in yards being divided by 1760, the number of yards in a mile, gives the number of miles which theſe diſtances contain.

The navigator may always know the height he is from the ſurface of the ſea, when he obſerves the hull of another ſhip, at the water edge, then he has the diſtance marked in the table againſt the height from which he obſerves; but if any part of the ſhip he obſerves is hid by the ſurface of the water, he muſt give a gueſs how high the part hid is; then if he adds the diſtance againſt that height expreſſed in yards, to that againſt the height he ſees, the ſame will be the true diſtance to the ſhip.

EXAMPLE. Suppoſe he obſerves a ſhip from a height of 15 yards, and the part of the ſhip hid is 5 yards; then the diſtance 6470 againſt 5 yards, added to the diſtance 14468 againſt 15 yards, gives 20938 yards or 12 miles nearly for the diſtance required.

We have not conſidered the refraction of the air, by which the ſhip may be ſeen a little farther than what is marked in the table. But if the ſhip is within the horizon, and the height of the part ſeen between the ſurface of the water and the horizontal line, then the diſtance anſwering to this height, ſubtracted from the firſt, gives that between the two ſhips.

ARTILLERY.

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ARTILLERY.

PART I.

WEIGHTS *and* MEASURES.

TO proceed with order in the enſuing work, it is proper to mention the neceſſary weights and meaſures uſed in Artillery, for the better underſtanding the uſe and conſtruction of the tables.

An inch is the leaſt common meaſure; 12 inches make a foot, 3 feet a yard, a pole is 16.5 feet, a furlong 40 yards, and a mile 1760 yards. Theſe meaſures are alſo ſub-divided into 10, 100, and 1000 parts.

Avoirdupois weight is uſed in Artillery, and in all heavy commodities; a drachm is the leaſt weight, 16 of which make an ounce, 16 ounces a pound, 14 pounds a ſtone, 112 pounds a hundred weight, 20 hundreds a ton.

As *French* weights and meaſures are proper to be underſtood in Artillery, we ſhall give the proportion between ours and theirs. The gentlemen of the Royal Society in *London*, in conjunction with thoſe of the Royal Academy of Sciences at *Paris*, are ſaid to have, with

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great accuracy, compared our weights and measures with those of *France*; the result of which is,

The *English* foot to the *French* royal, as 107 to 114. The *English* pound avoirdupois to the *French* pound marc, as 63 to 68. Whence 100 *French* pounds make very near 108; and therefore their hundred-weight is to ours, as 108 to 112; that is, as 27 to 28, according to this proportion.

The proportion of the *French* and *English* foot is nearly exact; for I tried two *French* sectors, the one made by *le Maire* seemed to be exactly divided, and I found that three *French* inches make 3.2 of ours; so that the *French* foot is to ours as 32 to 30, which is near 114 to 107; since if 114 be multiplied by 15, the product will be 1710; and 107 multiplied by 16, gives 1712; which exceeds the former by 2 only.

But the proportion of the *French* and our weights is by no means right, as will appear hereafter, when we give tables of shots. It is hard to judge how such a mistake could happen, unless the weights they compared were not those used in the Artillery there and here.

Before we proceed any farther, it will be necessary to premise some geometrical propositions, which ought to be known, in order to understand several parts of this work.

I. The diameter of the circle is to its circumference, as 113 is to 355 nearly.

II. The square of the diameter is to the area of the circle, as 452 to 355.

III. The cube of the diameter is to the solid content of a sphere, as 678 to 355.

IV. The cubes of the axes are to the solid contents of equialtitude cylinders, as 452 to 355.

V. The solid content of a sphere is to the circumscribed cylinder, as 2 to 3. These propositions are demonstrated in the Ninth Section of my Elements of Mathematics.

The

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The following table contains the weight of a cubic foot, expreſſed in ounces, of the ſeveral ſubſtances ſpecified, which I have for the moſt part taken from Mr. *Cotes*'s hydroſtatic lectures. Thoſe of gun metal have been computed from their mixture, and the caſt iron from the 9 pound ball, whoſe diameter is four inches, exceedingly near, according to Sir *Jonas Moor*.

Specific gravities of bodies.

Copper	9000	Steel	7645
Tin	7320	Marble	2700
Gun metal	8784	Dry oak	925
Caſt braſs	8000	Dry aſh	800
Lead	11325	Dry maple	755
Iron	7645	Dry elm	600
Caſt iron	7425	Dry fir	550
Shells	4892	Powder	880

For his father weighing ſeveral iron balls with a curious ſcale, found one nearly round, whoſe diameter was 6.63 inches, and weighed 41 pounds; from thence the diameter of a 9 pound ball is found to be 3.9995 inches, which being ſo very near 4 inches, by taking it as ſuch, no ſenſible error can happen in computation.

Having the weight of a cubic foot of theſe bodies, that of any parts may be found by proportion; and on the contrary, the weight of any part of a body being given, its ſpecific gravity, or the weight of a cubic foot, may be found. Thus a cubic foot, or 1728 cubic inches of gun metal, weigh 8784 ounces, or 549 pounds: then dividing 1728 by 9, we get 192 cubic inches; and dividing 549 by 9, we get 61 pounds. Hence 192 cubic inches of gun metal weigh 61 pounds.

Again: 1728 cubic inches of caſt iron weighing 7425 ounces, or 464 pounds and an ounce, which we ſhall neglect; then 1728 divided by 16, gives 108, and 464 divided by 116, gives 29. Hence 108 cubic inches of

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caſt iron weigh 29 pounds. Theſe two examples will be uſeful hereafter in finding the weight of guns.

A ſhell, whoſe diameter is 12¾, weighs 192 pounds when loaded, as will be ſhewn; and 355 is to 678, as the content or weight 192, is to the content or weight of the cube 366.69 made by its diameter: but the cube 2072.67 of 12¾, is to the cube 1728 of 12, as the weight 366.69 is to the weight 4892 of a cubic foot, or the ſpecific gravity of ſhells.

Again: a cylinder of powder, whoſe axis and diameter are each 3.42 inches, contains one pound, or 16 ounces, as will be ſhewn hereafter; and 355 is to 452, as the weight 16 ounces of the cylinder is to the weight 20.372 ounces of the cube made by its axis: but the cube 40 of 3.42 is to the cube 1728 of 12, as the weight 20.372 is to the weight 880 ounces of a cubic foot, or the ſpecific gravity of ordnance powder.

EXAMPLE I.

To find the diameter of an iron ball, whoſe weight is given, ſuppoſing that of a 9 pound is 4 inches. Say, the cube root, 2.08, of 9 pounds is to 4 inches, as the cube root of the given weight is to the diameter ſought; or if 4 be divided by 2.08, the cube root of 9, the quotient 1.923 will be the diameter of a one pound ball; which being continually multiplied by the cube root of the given weight, gives the diameter required.

This may be done in a ſhorter manner by making uſe of logarithms; for if the logarithm .2839793 of 1.923 be conſtantly added to the third part of the logarithm of the weight, the ſum will be the logarithm of the diameter. Suppoſe a ball to weigh 24 pounds, add the given logarithm .2839793, to the third part .4600704 of the logarithm 1.3802112 of 24, the ſum .7440494 will be the logarithm of the diameter of a ball weighing 24 pounds, which therefore is 5.5468 inches.

If

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If the weight be expreſſed by a fraction, the rule is ſtill the ſame; for inſtance, the diameter of a pound and a half ball, or of $\frac{3}{2}$, is found, by adding the logarithm .2839793, found above, to .0586971, one third of the logarithm of $\frac{3}{2}$; the ſum .3426764, will be the logarithm of the diameter required, which therefore is 2.2013 inches.

The diameter of an ounce ball is found, by ſubtracting .4013733, one third of the logarithm of 16, from the logarithm .2839793, of one pound; as this logarithm is leſs than the other, an unit muſt be added to it; then the difference .882606, will be the logarithm of the ball's diameter, which weighs an ounce. This logarithm being continually added to the third part of the logarithm of the weight, expreſſed in ounces, and an unit being taken from the ſum, the remainder will be the logarithm of the diameter: thus, let the ball weigh eight ounces, add .3010300, the third part of the logarithm of 8, to the logarithm .882606 of one ounce; the ſum .18363, after having ſubtracted unity, will be that of the diameter, which is 1.526 inches.

As the diameter of the bore, or the caliber of the piece, is made one twentieth part larger than that of the ſhot, according to the preſent practice, we have computed the following

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Diameters of the ſhots and calibers of Engliſh *guns.*

lb.	0	1	2	3	4	5	6	7	8	9	
0	0	1. 923	2. 423	2. 775	3. 053	3. 288	3. 498	3. 679	3. 846	4. 000	Diam.
	0	2. 019	2. 544	2. 913	3. 204	3. 668	3. 673	3. 861	4. 038	4. 200	Calib.
1	4. 143	4. 277	4. 403	4. 522	4. 635	4. 743	4. 846	4. 945	5. 040	5. 131	Diam.
	4. 349	4. 490	4. 623	4. 748	4. 866	4. 981	5. 088	5. 192	5. 292	5. 386	Calib.
2	5. 220	5. 305	5. 388	5. 469	5. 547	5. 623	5. 697	5. 769	5. 839	5. 908	Diam.
	5. 480	5. 570	5. 661	5. 742	5. 824	5. 893	5. 982	6. 057	6. 129	6. 203	Calib.
3	5. 975	6. 041	6. 105	6. 168	6. 230	6. 290	6. 350	6. 408	6. 465	6. 521	Diam.
	6. 273	6. 343	6. 410	6. 475	6. 541	6. 604	6. 666	6. 727	6. 788	6. 846	Calib.
4	6. 576	6. 631	6. 684	6. 737	6. 789	6. 840	6. 890	6. 940	6. 989	7. 037	Diam.
	6. 904	6. 962	7. 018	7. 076	7. 128	7. 182	7. 234	7. 287	7. 338	7. 383	Calib.

The

The numbers in the first horizontal line are units, and those in the first vertical column the tens: the other numbers under the one, and opposite to the others, are the respective diameters of shot and calibers. Thus to find the diameter of the shot, and the caliber of a 24 pounder, look for the number 2 at the side, and for 4 at top; then the number 5.547 under 4, and opposite to 2, will be the diameter of the shot in inches and decimals, and the number 5.824, under the first, the caliber of the 24 pounder. Again, to find the diameter of the shot, and the caliber of a 36 pounder; look for 3 at the side, and 6 at the top, then the number 6.350, under 6, and opposite to 3, will be the diameter of the shot, and the number 6.666 under it, the caliber of the 36 pounder. In the same manner may be found the diameter of the shot and the caliber of any gun, under a 60 pounder: those above 48 are not used.

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Diameters of the shots and bores of French *guns by inches and decimals of their measure.*

	0	1	2	3	4	5	6	7	8	9	
0	0	1. 889	2. 381	2. 726	3. 000	3. 253	3. 434	3. 615	3. 780	3. 931	Diameter.
	0	1. 950	2. 469	2. 827	3. 111	3. 351	3. 561	3. 749	3. 920	4. 076	Caliber.
1		4. 072	4. 203	4. 327	4. 444	4. 555	4. 661	4. 762	4. 859	4. 953	5. 043	Diameter.
		4. 222	4. 390	4. 487	4. 608	4. 723	4. 833	4. 938	5. 039	5. 134	5. 229	Caliber.
2		5. 130	5. 214	5. 295	5. 375	5. 451	5. 526	5. 599	5. 670	5. 739	5. 847	Diameter.
		5. 320	5. 407	5. 491	5. 584	5. 653	5. 730	5. 806	5. 880	5. 951	6. 061	Caliber.
3		5. 872	5. 937	6. 000	6. 062	6. 122	6. 182	6. 237	6. 297	6. 354	6. 409	Diameter.
		6. 089	6. 157	6. 222	6. 288	6. 349	6. 411	6. 468	6. 530	6. 589	5. 646	Caliber.
4		6. 463	6. 517	6. 569	6. 621	6. 672	6. 722	6. 771	6. 820	6. 868	6. 916	Diameter.
		6. 702	6. 758	6. 812	6. 866	6. 918	6. 971	7. 022	7. 072	7. 122	7. 172	Caliber.

This

This table is conſtructed upon the ſuppoſition that the diameter of a four pound ball is three *French* inches, according to their authors; and from thence, the difference between the logarithm of three inches, and one third of the logarithm of four pounds, gives the logarithm .2764347 of the diameter of a one pound ball, which being continually added to one third of the number of pounds of the ball, the ſum will be the logarithm of the diameter of that ball in inches and decimals. The windage of the *French* guns is but one twenty-ſeventh part of the ball's diameter; which, therefore, being added to the diameter, gives that of the caliber. Mr. *Saint Remy* gives a table of theſe diameters in page 136, vol. i. new edit. in inches and duodecimals, without mentioning how it was conſtructed. In page 82, he ſays, that *Butterfield* has computed it, and that it is very exact. *Butterfield* was an *Engliſh* mathematical-inſtrument-maker eſtabliſhed at *Paris*.

This table agrees nearly with that given by *Saint Remy*, p. 136, as appears from the following numbers, where lines and points are reduced into decimals of an inch.

The firſt column contains the weights of the ſhot, the ſecond their diameters in inches and decimals according to *Saint Remy*, and in the third the ſame diameters according to our tables. Hence, our diameters are greater as far as a thirty-ſix pound ſhot, and leſs above it. Therefore the *French* table has not been conſtructed from the rule that the weights of ſhots are as the cubes of their diameters, unleſs ſome errors have been committed in their computations.

lb.		
24	5.444	5.451
36	6.229	6.237
39	6.417	6.409
41	6.518	6.517
46	6.776	6.771

The following table has been computed upon the ſuppoſition, that the *French* foot is to the *Engliſh* as 114 is to 107, as we have ſhewn in page 2; and from thence, the logarithm of the diameter of a *French* pound is .3039558, expreſſed in *Engliſh* inches and decimals.

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As to the reſt of the diameters they are found in the ſame manner as before.

Diameters of the ſhots and bores of French *guns in* Engliſh *inches.*

	0	1	2	3	4	5	6	7	8	9	
0	0	2. 013	2. 537	2. 904	3. 196	3. 443	3. 659	3. 852	4. 027	4. 185	Diameter.
	0	2. 088	2. 631	3. 011	3. 315	3. 570	3. 794	3. 994	4. 180	4. 343	Caliber.
1	4. 338	4. 478	4. 610	4. 734	4. 853	4. 966	5. 074	5. 177	5. 277	5. 373	Diameter.
	4. 499	4. 554	4. 781	4. 910	5. 032	5. 150	5. 262	5. 365	5. 472	5. 571	Caliber.
2	5. 466	5. 555	5. 642	5. 726	5. 808	5. 887	5. 965	6. 041	6. 114	6. 186	Diameter.
	5. 668	5. 761	5. 851	5. 938	6. 023	6. 105	6. 185	6. 264	6. 341	6. 415	Caliber.
3	6. 256	6. 325	6. 393	6. 458	6. 523	6. 586	6. 648	6. 709	6. 769	6. 828	Diameter.
	6. 488	6. 559	6. 629	6. 698	6. 765	6. 830	6. 895	6. 958	7. 020	7. 080	Caliber.
4	6. 886	6. 943	6. 999	7. 054	7. 108	7. 162	7. 245	7. 266	7. 318	7. 368	Diameter.
	7. 141	7. 200	7. 258	7. 315	7. 372	7. 427	7. 513	7. 536	7. 589	7. 641	Caliber.

This

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This table ſerves to compare the *French* calibers to ours: for example, the diameter 5.808 of a 24 pound ball is ſomething more than 5.769, that of our 27. That 6.393, of their 32, nearly equal to 6.408, that of our 37. That 6.648 of their 36, nearly equal to 6.684 of our 42.

The diameter of a *French* 9 pound ſhot is 4.188 inches of our meaſure, and its cube 73.453; and as the diameter of our 9 pounder is 4 inches, and its cube 64; therefore the *French* weight is to ours as 73 453 is to 64, or as 70 to 61 nearly: which differs greatly from the ratio mentioned before. Therefore 100 *French* pounds make 114⅔ pounds, and not 108, as the former proportion gives.

The proof that this ratio is the neareſt that can be given by two figures, we ſhall ſuppoſe, with Sir *Jonas Moor*, that the diameter of a 9 pound iron ſhot is 3.9995 inches; then as 114 is to 107, as 3.9995 is to 3.7593 *French* inches, whoſe cube is 52.899, and 70 is to 61 as 9 to 7.8428 pounds *French* weight. Therefore the cube 52.899 is to the cube 27 of 3, as the weight 7.8428 is to the weight 4.0004 pounds of the ſhot, whoſe diameter is 3 *French* inches, which agrees nearly with the ſuppoſition of the *French*: but if the ratio 63 to 63 be ſuppoſed, a 9 pounder *Engliſh* weighs 8.3382; then by proportion the weight of a ſhot, whoſe diameter is 3 *French* inches, will be 4.2558 pounds, or above a quarter more than 4 pounds; which is certainly more than it is poſſible not to perceive.

Iron

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Iron grape shot from 1 to 39 ounces.

℥	0	1	2	3	4	5	6	7	8	9
0	0	.763	.9615	1.103	1.209	1.305	1.387	1.450	1.526	1.587
1	1.644	1.697	1.747	1.794	1.839	1.882	1.923	1.962	2.000	2.036
2	2.072	2.106	2.138	2.170	2.201	2.231	2.261	2.286	2.318	2.345
3	2.371	2.397	2.423	2.448	2.472	2.496	2.501	2.543	2.566	2.588

Whence

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Whence the diameter of any bullet is found, by dividing 1.6706 inches by the cube root of the number, which ſhews how many of them make a pound; or this may be done in a ſhorter manner. From the logarithm .2228756 of 1.6706 ſubtract continually the third part of the logarithm of the number of bullets in the pound, and the difference will be the logarithm of the diameter required.

Thus the diameter of a bullet, whereof 12 weigh a pound, will be found by ſubtracting .3597270, a third part of the logarithm of 12, from the given logarithm .2228756, or, when this logarithm is leſs than the former, an unit muſt be added, ſo as to have 1.2228756, and the difference .8631486 will be the logarithm of the diameter ſought; which is .7297 inches; obſerving that the number found will always be a decimal, when the logarithm which is to be ſubtracted is greater than that of one pound; becauſe the diviſor is greater than the dividend in this caſe.

From the ſpecific gravity of lead, the diameter of any bullet may be found from its given weight. For ſince a cubic foot weighs 11325 ounces by our table, and 678 is to 355 as the cube 1728 of a foot, or 12 inches, is the content of the ſphere, which therefore is 5929.7 ounces; and ſince ſpheres are as the cubes of their diameters, the weight 5929.7 is to 16 ounces, or one pound, as the cube 1728 is to the cube of the diameter of a ſphere which weighs a pound; which cube therefore is 4.66263, and its root 1.6706 inches, the diameter ſought.

Sir *Jonas Moor* makes this diameter 1.69 inches: though he was very curious in his experiments, yet as the ſpecific gravities have likewiſe been determined by *Cotes* and ſeveral eminent men, it would be a preſumption in me to determine which of the two diameters is the moſt accurate; for which reaſon we ſhall give two tables, one of each of theſe ſuppoſitions, leaving the choice to the impartial reader.

Diameters

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Diameters of leaden bullets from 1 *to* 39 *in the pound, according to the author.*

	0	1	2	3	4	5	6	7	8	9
0	0	1. 671	1. 326	1. 158	1. 05	. 977	. 919	. 873	. 835	. 803
1	. 715	. 751	. 730	. 711	. 693	. 677	. 663	. 650	. 637	. 626
2	. 615	. 605	. 596	. 587	. 579	. 571	. 564	. 557	. 550	. 544
3	. 538	. 532	. 526	. 521	. 517	. 511	. 506	. 501	. 497	. 493

Diameters of leaden bullets from 1 *to* 39 *in the pound, according Sir* Jonas Moor.

	0	1	2	3	4	5	6	7	8	9
0	0	1.690	1.341	1.172	1.064	0.988	0.930	0.883	0.845	0.812
1	0.784	0.760	0.738	0.719	0.701	0.685	0.671	0.657	0.645	0.633
2	0.623	0.612	0.603	0.594	0.586	0.578	0.570	0.563	0.556	0.550
3	0.544	0.537	0.532	0.527	0.521	0.517	0.512	0.507	0.503	0.498

The diameter of the muſket bores differ not above one fiftieth part from that of the bullet; for if the ſhot but juſt rolls into the barrel it is ſufficient. The government allows 11 bullets in the pound, for the proof of muſkets, and 14 in the pound, or 29 in two pounds, for ſervice: 17 for the proof of carabins, and 20 for ſervice; and 28 in the pound for the proof of piſtols, and 34 for ſervice.

As powder meaſures are uſeful in artillery, being more handy than weights, ſaving time, and are neceſſary in ricochet firing, we ſhall inſert here ſome experiments I made upon that ſubject in 1753, at the royal academy of artillery.

I. A cy-

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I. A cylinder, whose axis and diameter were two inches each, contained 3 ounces and 3 grains, or 51 grains; and as similar cylinders are as the cubes of their axis; if we say 51 grains are to 256 grains, or one pound, as the cube 8 of 2 inches is to the cube 40.166 of the diameter of a like cylinder holding one pound.

II. A cylinder, whose axis and diameter were 4 inches each, held 25 ounces and 10.5 grains, or 410.5 grains; whence 410.5 grains are to 256 grains, as the cube 64 of 4 inches is to 39.912, the cube of the axis of a cylinder holding one pound.

III. A cylinder, whose diameter and axis were 6 inches each, held 5 pounds 6 ounces and 6 grains, or 1382 grains. Hence 1382 : 256 : : 216 : 40.01 for the cube required.

IV. A two-inch cube held 4 ounces and 1 grain, or 65 grains; and as 452 is to 355, so is the cube 8 of the axis to the content of the cylinder, which therefore is 51.05. Hence 65 : 256 : : 8 : 40 : 117, the cube of the axis.

V. A six-inch cube held 6 pounds 13 ounces and 13 grains, or 1757 grains; so then 452 : 355 : : 1757 : 1379.944, or 1380, the content of the cylinder; and if 1380 : 256 : : 216 : 40.07, this fourth term will be the cube of the axis required. Hence a medium of these five experiments gives 40.053 cubic inches, whose cube root 3.42 will be the diameter of a cylinder holding a pound of powder.

From hence we may deduce the specific gravity of powder, which is no more than the content of a cubic foot expressed in ounces. Now since 355 is to 452, as the content 16 ounces of the cylinder is to 20.372, the content of the cube of its axis, and the cube 40 of the axis is to the cube 1728 of 12 inches, or a foot, as 20.372 ounces to 880 ounces contained in a cubic foot of powder.

Sir *Jonas Moor* found by several experiments the diameter of a cylinder holding a pound of powder to be 3.165 inches. *Dia-*

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Diameters and heights of cylindric powder measures from 1 *to* 39 *ounces, according to the author.*

℥	0	1	2	3	4	5	6	7	8	9
0	0	1.357	1.710	1.957	2.154	2.321	2.467	2.596	2.714	2.830
1	2.924	2.963	3.107	3.191	3.271	3.347	3.420	3.490	3.557	3.622
2	3.684	3.744	3.803	3.859	3.915	3.968	4.021	4.072	4.121	4.170
3	4.217	4.263	4.309	4.353	4.397	4.439	4.481	4.523	4.563	4.603

The logarithm of an ounce is .1326467; the other numbers are found, by adding one third of the logarithm of the number of ounces. Thus the number of 8 ounces is found by adding .3010300, one third of the logarithm of 8 to that of one ounce, which gives .4336767 for the logarithm of the number sought; which therefore is 2.714.

Diameters and heights of cylindric powder measures from 1 *to* 39 *pounds, according to the author.*

℔	0	1	2	3	4	5	6	7	8	9
0	0	3.420	4.309	4.932	5.429	5.848	6.214	6.541	6.824	7.114
1	7.368	7.606	7.830	8.041	8.243	8.434	8.618	8.794	8.963	9.126
2	9.283	9.435	9.583	9.726	9.865	10.00	10.13	10.26	10.38	10.51
3	10.63	10.74	10.86	10.97	11.08	11.16	11.29	11.45	11.50	11.60

Diameters

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Diameters of cylindric powder measures, when the diameter is to the axis as 2 to 3, according to the author.

℔	0	1	2	3	4	5	6	7	8	9
0	0	1.181	1.491	1.710	1.880	2.027	2.155	2.268	2.371	2.472
1	2.554	2.588	2.714	2.788	2.857	2.924	2.988	3.049	3.164	3.164
2	3.218	3.271	3.322	3.371	3.420	3.466	3.513	3.557	3.600	3.643
3	3.684	3.724	3.764	3.802	3.841	3.878	3.915	3.951	3.986	4.021

lb.	0	1	2	3	4	5	6	7	8	9
0	0	2.988	3.764	4.308	4.743	5.109	5.428	5.714	5.961	6.215
1	6.436	6.644	6.840	7.024	7.201	7.368	7.529	7.682	7.830	7.972
2	8.109	8.242	8.372	8.496	8.618	8.736	8.849	8.963	9.068	9.181
3	9.286	9.382	9.496	9.583	9.679	9.769	9.863	10.00	10.05	10.13

These diameters are found, if those of the former tables be divided by 1.1447, the cube root of $\frac{3}{4}$.

As I look upon these experiments to have been made with great accuracy, this difference can proceed from no other cause, than that the grain of the powder was something finer in his time than at present. The changing the size of the grains, is attended with many inconveniencies without the least advantage; for the powder measures made at one time are either larger or less than what they should be at another, whereby great mistakes are made in loading of pieces. Sometimes more, and other times less powder is used than intended; and to change them continually, is attended with ex-

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pences, and cannot always be done abroad, where they have no conveniency to do it: ſuch miſtakes were made at *Minorca* ſome years ago, where the powder meaſure held 35 pounds inſtead of 30; and at the end of the ſeaſon, the officer could not account for the ſpending ſo much more powder than he intended, till he found the miſtake by examining the meaſure.

When the grains are made as large as we do at preſent, it happens that ſome of them are much ſmaller than others, and the ſmall take fire ſooner than the reſt, by which the force of ſome is partly expended before the reſt is fired, and conſequently the total force is not ſo great as it would be, if the grains were nearly of the ſame ſize.

It has been imagined by ſome, that the large grained powder is ſtronger than the ſmall: but Captain *Deſaguliers* made ſome experiments with grained and mealed powder; both which carried the ſhot the ſame diſtance. It may be preſumed, that powder was not grained at its firſt diſcovery, but in courſe of time experience ſhewed, that it kept longer in grains than otherwiſe; for which reaſon this cuſtom is followed by all nations, and is undoubtedly the beſt.

Diameters and heights of cylindric powder meaſures, holding from 1 *ounce to* 19, *according to Sir* Jonas Moor.

℥	0	1	2	3	4	5	6	7	8	9
0	0	1.257	1.583	1.811	1.994	2.148	2.282	2.403	2.512	2.613
1	2.706	2.793	2.876	2.953	3.027	3.098	3.165	3.230	3.292	3.352

These diameters are in inches and decimals.

Diameters

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Diameters and heights of cylindric powder meaſures, holding from 1 *to* 19 *pounds.*

lb.	0	1	2	3	4	5	6	7	8	9
0	0	3.165	3.988	4.565	5.024	5.412	5.751	6.05	6.330	6.583
1	6.890	7.039	7.245	7.442	7.628	7.805	7.975	8.138	8.295	8.391

This laſt table is conſtructed in this manner; multiply continually the cube 31.705, of 3.165, by the number expreſſing the weight of powder, and the product will be the cube of the diameter and axis of the cylinder ſought. Or thus, add continually .5003737, the logarithm of 3.165, to the third part of the logarithm of the number ſhewing the weight, then the ſum will be the logarithm of the diameter required.

Thus one third .2006866, of the logarithm of 4, being added to the logarithm .5003737, gives .7010603, for the logarithm of the diameter of a cylinder, holding 4 pounds of powder, which is 5.024 inches.

The diameter of a cylinder, holding an ounce of powder, is found by ſubtracting one third of .4013733, the logarithm of 16, from the logarithm .5003737, then the difference .0990004, will be the logarithm of the diameter required; which being continually added to one third of the logarithm of the given number of ounces, gives the logarithm of the diameter ſought.

As powder meaſures are more convenient, when their axis is longer than their diameters, we ſhall give the

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Diameters of cylindric powder meaſures, when the diameter is to the height, as 2 to 3, according to Sir Jonas Moor.

$\frac{3}{3}$	0	1	2	3	4	5	6	7	8	9
0	0	1.097	1.382	1.582	1.742	1.876	1.994	2.099	2.194	2.282
1	2.364	2.440	2.512	2.580	2.644	2.706	2.765	2.820	2.874	2.926

lb.	0	1	2	3	4	5	6	7	8	9
0	0	2.765	3.483	3.988	4.389	4.728	5.024	5.289	5.530	5.751
1	5.957	6.149	6.330	6.501	6.664	6.819	6.967	7.104	7.241	7.325
2	7.505	7.628	7.749	7.863	7.975	8.085	8.191	8.204	8.396	8.495

These two laſt tables are conſtructed, by multiplying continually the diameter in the two former tables, by the cube root .873 of $\frac{2}{3}$, then the product will give the diameters of cylinders, holding the ſame quantity of powder, or elſe by adding ——.0586971, the logarithm of .873, or the third part of that of $\frac{2}{3}$, to the logarithm .5003737, found above; then the ſum .4416766, being continually added to one third of the logarithm of the number expreſſing the weight, the ſum will be the logarithm of the diameter ſought.

For example, to find the meaſure that ſhall hold 28 pounds: the logarithm of 28 is 1.4471580, one third of which being added to the given logarithm .4416766, gives .9240626, for the logarithm of the diameter required, which therefore is 8.396 inches.

This rule is proved from the known property in geometry, that equal ſolids have their baſes and altitudes reciprocally proportional. Hence, if *a* expreſſes the diameter of the baſe or altitude, and *x* the diameter of

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the baſe of the cylinder required; then becauſe the diameter x of the baſe is to its altitude as 2 to 3 by ſuppoſition, the altitude will be $\frac{3}{2}x$; and hence, $a^3 = \frac{3}{2}x^3$, by the condition of the problem, or $\frac{2}{3}a^3 = x^3$; the cube root of which is $a^3\sqrt{\frac{2}{3}} = x$.

In the ſame manner may be found the diameter of a cylinder, which is to its altitude in any other given ratio, ſuch as 1 to 2, or as 3 to 5.

As it is neceſſary that an artillery officer ſhould know how to compute the number of ſhot contained in a ſquare or oblong pile, finiſhed or unfiniſhed, we ſhall give here a method for finding the number of ſhot more general than that in our Elements of Mathematics, page 98, deduced from a moſt compendious principle.

INVESTIGATION *of a general rule for finding the ſums of ſeries's.*

If z expreſſes the number of terms of a ſeries, whoſe ſum can be expreſſed by the product of factors that are in an arithmetical progreſſion; to find the z or general term of that ſeries.

N. B. The general term of a ſeries is ſuch an expreſſion compoſed of a variable z and conſtant quantities, that when z is made equal to 0, 1, 2, 3, or 1, 2, 3, 4, it gives the firſt, ſecond, third, fourth term of that ſeries.

It is evident, that by diminiſhing the value of z by the common difference n of the factors, the ſum will be diminiſhed by the laſt term, and the difference between theſe two ſums will be the z or general term required.

Thus if $z.\ z+n.\ z+2n.\ z+3n$, be the ſum of any ſeries, by writing $z-n$ for z, we get $z-n.\ z.\ z+n.\ z+2n$: which ſubſtracted from the firſt, gives $4n.\ z.\ z+n.\ z+2n$, for the general term required.

N. B. The points between the factors ſignify multiplication.

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General RULE.

From the sum of a series, to find its general term; *multiply the sum by the number of factors and the common difference, and strike out the last factor.*

N. B. Whether the sum is multiplied by a constant number, or the factors decrease or increase, the rule is the same.

Thus the sum az gives a for a general term; $z.\ z+1$ gives $2z$; the sum $z.\ z-1.\ z-2$ gives $3\ z.\ z-1$, and $z.\ z+n.\ z+2n.\ z+3n$, gives $4n.\ z.\ z+n.\ z+2n$.

General RULE.

From the general term of a series to find the sum of any number z of terms.

Increase the factors by one more factor, and divide by the number of factors thus increased, and by the common difference.

Thus the general term a gives az for the sum, az gives $\frac{1}{2}az.\ z+1$; $z.\ z+1$ gives $\frac{1}{3}z.\ z+1.\ z+2$, and $z.\ z-n.\ z-2n$, gives $\frac{1}{4n}z.\ z-n.-z-2n.\ z-3n$.

Observe, when the first value of z is 0, the factors must be of a decreasing progression; but if it is any number of an increasing progression, as examples will shew.

EXAMPLE I.

Let the series be any arithmetical progression as a, $a+n$, $a+2n$, $a+3n$, &c. whose general term is $a+zn$, when the values of z are 0, 1, 2, 3, and the sum $az+\frac{1}{2}n.\ z-z-1$. of z terms. If 1, 2, 3, 4; then $a=n=1$, and $\frac{1}{2}z.\ z+1$, the sum of z terms. If 5, 7, 9, 11, then $a=5$, $n=2$, and $5z+z.\ z-1$ or $z.\ z+4$, the sum of z terms.

EXAMPLE

Example II.

Let the series be the squares of an arithmetical progression, as $a\,a$, $\overline{a+n}^2$, $\overline{a+2n}^2$, &c. whose general term is $\overline{a+zn}^2$ or $aa+2nz+nnzz$, and 0, 1, 2, 3, the values of z: hence the sum of the two first terms is $aaz+nz.z-1$, and since $zz=z+z.z-1$, whose sum is $\frac{1}{2}z.z-1+\frac{1}{3}z.z-1.z-2$, or $\frac{1}{6}z.z-1.22-1$, when reduced under the same denomination.

Therefore $aaz+nz.z-1+\frac{1}{6}nnz.z-1.2z-1$, is the Sum of z terms of that series.

Thus if the series is the squares of the natural numbers 1, 2, 3, 4, then $a=n=1$, and $z+z.z-1+\frac{1}{6}z.z-1.2z-1$, or $\frac{1}{6}z.z+1.2z+1$, when reduced under the same denomination.

If the series is 1, 9, 25, 49, that is the squares of the numbers 1, 3, 5, 7, 9, then is $a=1$, $n=2$, and $z+2z.z-1+\frac{2}{3}z.z-1.2z-1$, or $\frac{1}{3}z.2z+1.2z-1$, the sum when reduced. If $z=10$, then will 1330 be the sum of the 10 first terms.

Example III.

If ab, $a+1.b+1$, $a+2.b+2$, be the series, which is that of the horizontal range of a rectangular pile of shot, whose general term is $a+z.b+2$, or $ab+\overline{a+b}.z\times zz$, and 0, 1 2, 3, 4, the values of z; the sum is therefore $abz+\overline{a+b}.\frac{1}{2}z.z-1+\frac{1}{6}z.z-1.2z-1$, by examp. II.

This series may be reduced to A. $2a+z-1\times 2b+z-1+\frac{1}{3}z+1.z-1.x$ by $\frac{1}{4}z$. For $2a+z-1$, multiplied by $2b+z-1$, gives $4ab+\overline{2a+2b}.z-1+z-1.z-1$, and $z-1.z-1$ added to $\frac{1}{3}z+1.z-1$, and the whole divided by 4 gives the first sum.

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General RULE *for an incomplete pile.*

To twice the length and breadth of the upper ſurface, add the corner row leſs one.

To the product of theſe two numbers add one third of the product, the corner row leſs one by the corner row more one, and multiply the ſum by one fourth of the corner row.

Thus, if the ſides of the upper ſurface are 20 by 4, and the corner row 6;

Then the ſum of 40 and 5, multiplied by the ſum of 8 and 5, gives — — — — 585

One third of 7 multiplied by 5, gives — — $11\frac{2}{3}$

Then the ſum $596\frac{2}{3}$ of theſe two products, multiplied by 6 and divided by 4, gives 895 for the number of ſhot contained in that pile.

CASE I.

When the pile is complete then $b=1$, and the ſum A, becomes $3a+2z-1x$ by $\frac{1}{6}z.z+1$. Which gives this

General RULE *for a complete pile.*

To three times the upper row add twice the corner row leſs one.

Multiply the ſum by the product of the corner row, by the corner row more one, and divide the product by 6.

If the upper row be 20, and the corner one 12; then 3 times 20, added to 23, gives — — — 83

Multiply 83 by 12, this product by 13, and divide by 6, which gives 2158 for the number of ſhot required.

CASE II.

When both a and b become unity, the ſum A becomes $\frac{1}{6}z.z+1,2z+1$, which gives this

General

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General RULE *for a complete ſquare pile.*

Multiply the corner row by that row more one, multiply this product by twice the corner row more one, and divide by 6.

If the corner row be 50, then $\frac{1}{6}$ 50 . 51 . 101, or 25 . 17 . 101, gives 42925 for the number of ſhot required.

N. B. By dividing before the multiplication is performed, as we have done, and which is always poſſible, the operation becomes ſhorter.

CASE III.

When $b=a+1$, the ſeries becomes $a.a+1, a+1.a+2$, and if each of theſe terms be divided by 2, it will be that of a triangular pile, and becauſe $b=a+1$, the ſum A divided by 2, gives $2a+z-1+2a+z+1+\frac{1}{3}z+1.z-1$ × by $\frac{z}{8}$.

General RULE *for triangular incomplete piles.*

To twice the ſide of the upper row, add the corner row leſs one, and the corner row more one.

To the product of theſe two numbers, add one third of the product, the corner row leſs one by the corner row more one, and multiply the ſum by one eighth of the corner row.

If the ſide of the upper row be 26, and the corner 20; then twice 26 added to 19, gives 71; twice 26 added to 21, gives —— —— —— 73
And 71 multiplied by 73, gives —— 5183
One third of 21 multiplied by 19 —— 133
The ſum 5316, multiplied by 20, and divided by 8, gives 13290, for the number of ſhot contained in the pile.

CASE

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CASE IV.

When a is unity, the ſum in the laſt caſe becomes $\frac{1}{6}z.z+1.z+2$, which gives this

General RULE *for a complete triangular pile.*

Multiply the baſe by the baſe one more, this product by the baſe more two, and divide by 6.

If the baſe be 40, then 40 by 41, by 42, and the product divided by 6, gives 11480 for the number of ſhot contained in this pile.

Theſe are all the different rules that can be given upon that ſubject, and to ſave the reader the trouble of computation, we ſhall inſert here four large tables containing the number of ſhot in 2912 complete piles. The firſt column of theſe tables contains the number of the corner rows, and the upper horizontal line the number of the upper ranges. The number of ſhot in a pile is againſt the number of the corner row, and under that of its upper range. The laſt column contains the number of ſhot in a triangular pile, oppoſite to the number of its corner row in the firſt column.

PART II.

Conſtruction of GUNS.

WHAT has been ſaid in the Introduction, with regard to the proper length of pieces, and the properties of different chambers in mortars, will enable us to form ſome general conſtructions of pieces, deducted from experiments and theory, and therefore leſs liable to exceptions, than thoſe hitherto given by others, which

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which ſeem to have no other foundation, than the particular fancy of the contriver, and generally a bare imitation of others. Before we proceed any farther, it is neceſſary to give the names of the ſeveral parts of which pieces are compoſed, in order that what is ſaid may be clearly underſtood.

Names of the ſeveral parts of a gun.

Plate I. Fig. I.

A B. The length of the gun.
A E. The firſt reinforce.
E F. The ſecond reinforce.
F B. The chace.
H B. The muzzle.
A h. The caſcable.
A C. The breech.
C D. The vent field.
F I. The chace girdle.
r s. The baſe ring and ogee.
t. The vent aſtragal and fillets.
p q. The firſt reinforce ring and ogee.
v w. The ſecond reinforce ring and ogee.
x. The chace aſtragal and fillet.
z. The muzzle aſtragal and fillets.
n. The muzzle mouldings.
m. The ſwelling of the muzzle.
A i. The breech mouldings.

The vacant cylinder, wherein the powder and ball are lodged, is called the Bore, and the entrance of the bore, the Mouth of the Gun. The cylindric parts T, by which the gun is fixed upon its carriage, are called Trunnions; and the handles on braſs pieces, are called Dolphins, from the fiſh whoſe form they repreſent. The diameter of the bore is called the Caliber of the Piece. Laſtly, the difference between the diameters of the ſhot and the bore, is called the Windage of the Gun.

REMARKS

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REMARKS.

The length of a gun is always reckoned from the hind part of the baſe ring, or beginning of the caſcable, to the extremity of the muzzle. The ſecond reinforce begins at the ſame circle where the firſt ends; and the chace at the ſame circle where the ſecond reinforce ends.

The firſt reinforce includes the baſe ring, ogee next to it, the vent field, vent aſtragal, and firſt reinforce ring; the ſecond reinforce, the ogee next to the firſt reinforce ring, and the ſecond reinforce ring; and the chace, the ogee, next to the ſecond reinforce ring, the chace girdle and aſtragal, the muzzle and aſtragal. The trunnions and dolphins are always placed on the ſecond reinforce; the firſt, ſo as the breech part may weigh ſomething more than the muzzle part, to prevent the piece from kicking up behind when it is fired; which it will always do ſo long as the center line is placed below that of the piece, as has been the cuſtom ever ſince their invention. On the contrary, the dolphins are ſo placed, that when the gun is ſuſpended thereby, the breech and muzzle parts may equally poiſe.

The artilleriſts here differ in the names of ſeveral parts; not one of them can tell preciſely how far the muzzle reaches, nor the caſcable; for ſome call the ſwelling the muzzle, others the breech mouldings, the caſcable, and ſay, that the button is a ſeparate part by itſelf, and not included in the caſcable.

As no one has hitherto attempted to write upon Artillery in *Engliſh*, and to fix the names, it is no wonder that the practitioners differ, ſince they have no guide to go by. The only thing we could do, was to fix the names of the parts in the moſt convenient manner to their conſtruction, and to prevent confuſion. We have called the part from the beginning of the muzzle aſtragal to the mouth, the Muzzle; becauſe that aſtragal deriving its name from the muzzle, it ſeems therefore that

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These Tables are to be inserted immediately after Page 26, Signature [C].

I	16	17	18	19	20	D
10	1210	1265	1320	1375	1430	55
11	1496	1562	1628	1694	1760	66
12	1820	1898	1976	2054	2132	78
13	2184	2275	2366	2457	2548	91
14	2590	2695	2800	2905	3010	105
15	3040	3160	3280	3400	3520	120
16	3536	3672	3804	3944	4080	136
17	4080	4233	4386	4539	4692	153
18	4674	4845	5016	5187	5358	171
19	5320	5510	5700	5890	6080	190
20	6020	6230	6440	6650	6860	210
21	6776	7007	7238	7469	7700	231
22	7590	7843	8096	8349	8602	253
23	8464	8740	9016	9292	9568	276
24	9400	9700	10000	10300	10600	300
25	10400	10725	11050	11375	11700	325
26	11466	11817	12168	12519	12870	351
27	12600	12978	13356	13734	14112	378
28	13804	14210	14616	15022	15428	406
29	15080	15515	15950	16385	16820	435
30	16430	16895	17360	17825	18290	465
31	17856	18352	18848	19344	19840	496
32	19360	19888	20416	20944	21472	528
33	20944	21505	22066	22627	23188	561
34	22610	23205	23800	24395	24990	595
35	24360	24990	25620	26250	26880	630
36	26106	26862	27528	28194	28860	666

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The foregoing rules ar lar occaſions, and to ſatisfy the curious v egoing tables may be performed in an e er rows from 10 to 36, and is an arith he number of ſhot in the upper ranges ural numbers from 1 to 60.

The ſecond column, th f the natural numbers; thus to unity es 14 for the next pile; to this add th inued at plea- ſure, or any one may be

The laſt column under ave the ſame corner row, and are alw 1; thus the difference 55 againſt the nd by adding continually the next corne non difference of the next line; and 12

Having the ſecond of ſt of the differences, the other colum me horizontal line. Thus the firſt pyra 55, their ſum 440 is the content of th whoſe upper row is 3. Again, the p fference 210; the ſum 6230 of 210 an

The column of differe by adding the common difference to th find the true number: thus the conten add the difference 300 to 15400, o hat number.

Mr. *St. Remy* gives a rom 1 to 20, and upper ones from 1 e, excepting three numbers, being th n the corner rows at 10, becauſe any ke nearly the largeſt. The upper row ether contain the number of 1620 diff

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that the muzzle ſhould reach ſo far. As to the caſcable, it cannot properly be determined otherwiſe than we have done; ſince it is commonly ſaid, that a piece is of ſuch a length, excluſive of the caſcable; it agrees likewiſe with what general *Armſtrong* ſays in his Conſtruction, as well as the diſtinction made by the founders and practitioners.

Formerly pieces were diſtinguiſhed by the names of Sakers, Culverins, Cannon, and Demi-cannon; but at preſent their names are taken from the weight of their ſhot; as for example, a 12 or 24 pounder, carries a ball of 12 or 24 pounds weight.

As moſt conſtructions of authors agree in general, and differ only in ſome particulars, we ſhall give that of general *Armſtrong*'s, formerly ſurveyor-general of the ordnance, which appears to me leſs deficient than any that have hitherto been given, which are

General RULE *for braſs and iron guns.*

The length of the gun being divided into 7 equal parts; the length of the firſt reinforce A E, is two of theſe parts; the ſecond E F, one, and a diameter of the bore; ſo that the chace F B is four of theſe parts, wanting a diameter of the bore.

The diſtance from the hind part of the baſe ring, to the beginning of the bore, that is, the breech A C, is always equal to the thickneſs of the metal at the vent. The trunnions T, are always a caliber in length, and as much in diameter, clear of the ſecond reinforce ring, and placed in ſuch a manner, that a right line drawn through their centers touches the lower part of the bore, as in the fourth figure, where that line is marked a. b, and paſſing through the third diviſion; that is to be three ſevenths from the hind part of the baſe ring. The length of the caſcable A h, is always two calibers and a quarter.

Theſe

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These divisions are in general made by all nations, only the trunnions are placed half a caliber more backward by the *French* *.

General dimensions of brass guns.

The caliber of the gun is divided into 16 equal parts.

The thickness of metal at the base ring from the bore, is —— —— —— 16.

At the end of the first reinforce ring, —— 14.5

At the same place, for the beginning of the second reinforce, —— —— 13.5

At the end of the second reinforce, — —— 12.5

At the same place for the beginning of the chace, —— —— —— 11.5

At the end of the chace or muzzle, the mouldings excluded, —— —— — 8.

MOULDINGS.

Breadth of the { base ring, — — — 1.5 inches, ogee, next to the base ring, — — 2.

From the ogee to the fore part of the astragal, a caliber.

The fillets of the astragal, are each — .28

The astragal, or half-round — — .56

Total of the astragal and fillets, — — 1.12

At the first and second reinforce ring, the fillets are — — — .25

Breadth of the first and second reinforce rings — — — 1.25

The ogees next to these rings, — — 1.5

The fillets at the muzzle, — — .25

* This figure does not answer to the following constructions, but it is sufficient to shew the reader how to proceed, according to the given dimensions.

The

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The muzzle ogee, in a 12 pounder and upwards, is 1.25 inches; but in a 9 pounder and under, it is an inch only. The chace girdle and aſtragal is one caliber. The ſpace from the mouth of the gun to the muzzle aſtragal, in an 18 pounder and upwards, is equal to a diameter of the ſecond reinforce ring; but in a 12 pounder and under, it is equal to the diameter of the firſt reinforce ring.

The riſing of the mouldings at the firſt and ſecond reinforces, is an eighth of an inch; and the riſing of the baſe ring is determined by laying a ruler to the extremities of the firſt and ſecond reinforce mouldings. The ſwelling of the metal at the muzzle is always equal to the diameter of the ſecond reinforce ring.

CASCABLE.

From the hind part of the baſe ring, to the fore part of the fillet next to the bottom, $\frac{1}{3}$ of a caliber.

From the fore part of the fillet next to the button, to the centre of the button, one caliber.

From the hind part of the baſe ring, to the hind part of the fillet, between the two * ogees, $\frac{1}{6}$ of a caliber.

Diameter of the fillet next to the button, 1.5 caliber.

Diameter of the neck, $\frac{3}{4}$ of a caliber.

Diameter of the button, ſomething more than a caliber, it is ſix inches in a 24 pounder.

It muſt be obſerved, that the ſhell at the vent is 3 inches broad, and reaches from the baſe ring, to within a quarter of an inch of the vent aſtragal, leaving that ſpace for the eaſe of turning, and the vent is a fifth part of an inch.

* The reader muſt obſerve, that general Armſtrong made two ogees, though there is but one marked here.

General

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General dimenſions for iron guns.

The caliber of the gun is here divided into 14 equal parts.

The thickneſs of metal at the vent from the bore, is —— —— ——	16 parts.
At the end of the firſt reinforce — —	14.5
At the beginning of the ſecond reinforce,	13.5
At the end of the ſecond reinforce, ——	12.5
At the beginning of the chace, ——	11.5
At the end of the chace or muzzle, ——	8.

As to the mouldings, and the reſt of the dimenſions, they are much the ſame as before, only the diameter of the vent is here one fourth of an inch, without any reaſon given for it.

The lengths of the guns, according to this gentleman, were as follows; the 32 pounder braſs, 10 feet; the 24 and 18 pounders, 9.5 feet; the 12 pounder, 9; the ſix, 8; the three, 7; and the 1.5 pounder, 6 feet.

The iron 32 pounder, 9.5 feet; the 24 and 18 pounders, 9; the 12, eight; the 9, ſeven; the 6, ſix and half; and the 3, four and half feet.

Some of theſe dimenſions have been altered ſince for others, grounded upon no better reaſon than the former.

The reader may eaſily perceive the perplexity of theſe conſtructions, ariſing from the different ſcales that are uſed without the leaſt neceſſity. That the greateſt part of the mouldings ſhould have the ſame dimenſions, from a 3 pounder to one of 32, appears contrary to reaſon, and eſpecially contrary to the rules of architecture; from whence they have been taken. To make as many mouldings in iron guns, which are rough and not turned, as in braſs ones, is another blunder; but theſe are trifles in regard to the abſurdities in general committed in theſe conſtructions; which cannot better be diſcovered, than by examining all the parts ſeparately, each in their order.

Length

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Length of guns.

If the continual changing the length of pieces be conſidered, it will appear evident, that practice alone is inſufficient to determine that which is the beſt; and if the experiments hitherto publiſhed on that account are examined with ſome attention, it will be found, that for want of proceeding from proper principles, the reſult of them is erroneous and inconcluſive.

For the greateſt part of them were made to diſcover ſuch a length as ſhould carry the ſhot fartheſt, without mentioning what the charge ſhould be; believing that the greater the velocity of the ſhot is, the more its execution would be: but it has been found on the contrary by experience, that a velocity which is ſufficient to carry the ſhot juſt through a wall, does more execution than one that is greater. Others, ſuch as Mr. *Dumetz*, and the late general *Armſtrong*, endeavoured to find the beſt length of a piece, when loaded with two thirds of the ſhot's weight; and to attain which, Mr. *Dumetz* made uſe of different calibers, which had all the ſame length, *viz.* 10 feet, and he found that the 24 pounder carried its ſhot fartheſt.

Now, what can be concluded from theſe experiments? Nothing more, as I conceive, than that 10 feet is a better length for a 24 pounder, loaded with that charge, than for any ſmaller caliber: but it does not determine, that this length is ſuch, as to carry the ſhot fartheſt of any other; for we are not certain, whether one of 8 or 9 feet long would not be better than this, ſince no trial has been made to ſhew that it would not. Beſides, we are as much at a loſs as ever, to know what are the beſt lengths for ſmaller or greater calibers.

From the experiments made by general *Armſtrong* it was concluded, that 9.5 feet was the beſt length for a 24 pounder, though that of 9 feet produced the greateſt range.

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As theſe pieces were all of the ſame weight, it is plain that ſome of them were too ſtrong in proportion to their length; and if they had been reduced to a proper ſize, their ranges might probably have changed: but ſuppoſe this is in reality the beſt length for a 24 pounder, we are nevertheleſs in the dark with reſpect to the other calibers. So that the moſt that can be made of theſe experiments, is, that the length of the 24 pounder has been determined nearly, with regard to the charge made uſe of.

But it has been found ſince by experiments, that 8 pounds of powder are ſufficient for a 24 pounder, when it is to make a breach; for the *French* uſed no more all the two laſt wars in all their ſieges. This being the caſe, all former experiments are exploded, and conſequently others ought to be made, in order to determine the beſt length for that charge.

But are we certain that this charge is the beſt that can be uſed? I think by no means; for we have found, that one fourth of the weight of the ſhot is ſufficient for field-pieces, and even a leſs one. And we are not certain, that the ſame charge might not do in battering pieces, or on board of ſhips; ſo that new trials ſhould be made firſt, to know the beſt charge before the lengths of the pieces can be determined.

The making ſmall calibers longer in proportion than great ones, is attended with many inconveniences and of no advantage, ſo far as I can judge, ſince there is no neceſſity for their carrying as far as the heavy ones, which I ſuppoſe was the reaſon the artiſts went upon; but this ſuppoſition is erroneous; becauſe there is but one certain length that is better than any other, greater or leſs, as we ſhall ſhew; and therefore they may as well be too long as too ſhort.

Another inconveniency attends this practice, which is, that ſome of theſe pieces weigh above twice more than they ought to do, according to the moſt heavy conſtruction, whereby their carriage from place to place becomes

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becomes more troubleſome, and the expence at leaſt one third more.

Laſtly, when the lengths of pieces are not proportioned to the diameters of their ſhot, the experiments made with one caliber will not be of any uſe to any other, nor the dimenſions uſed; and therefore as many experiments muſt be made as there are different calibers, as well as ſo many different conſtructions, in order to make them equally good and ſtrong; and I may add, that this practice is the principal reaſon that ſo little improvement has been made in the conſtruction of pieces, and that ſo much confuſion is met with in them; whereas, if they are all the ſame number of diameters long, one general conſtruction will be ſufficient for all thoſe made of the ſame metal; and when the dimenſions of any one piece have been determined by experiments, it will ſerve for them all; the pieces will be ſimilar, and their weights in the ſame proportion to that of their ſhot. Finally, the conſtruction of all kind of pieces will be ſo ſhort and eaſy, as that they may be comprehended in a few leaves, as will be ſeen hereafter.

Since then neither practice, nor any theory hitherto publiſhed, no more than the experiments made in *England* or *France*, have as yet furniſhed us with any ſatisfactory rule to proceed by, and yet Artillery cannot be improved without it; we ſhall endeavour to ſhew here, both from theory and ſome unexceptionable experiments, that there is a certain length of a gun better than any other longer or ſhorter, whereby it will carry its ſhot the fartheſt poſſible. For general *Williamſon* of the Artillery made many experiments at *Minorca*, which are related in the introduction; whereby it appears that an eighteen pounder, which weighed 3900, and length 9 feet, carried farther than another eighteen pounder that weighed 5100, and was 11 feet long, when equally loaded, and with the ſame angle of elevation; it was found likewiſe, that nine pounds of powder was the beſt charge, and carried the ſhot farther than any other. From

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whence it appears, that the greateſt length of this caliber ought not to exceed 9 feet; but whether it might not be leſs has not yet been tried.

Now as 9 feet is 21 diameter of the ſhot nearly, and it is very probable that all calibers, proportionably long and charged, will produce ſimilar effects, we may draw this concluſion, *that the length of pieces which carry their ſhot fartheſt does not exceed* 21 *diameter of its ſhot*; and *that their beſt charges are equal to half the weight of their ſhot.*

This will receive no ſmall degree of certainty from what we have proved in the appendix to this work, page 122, where we have ſhewn, that the greateſt velocities which cannon ſhot of different calibers can have, are always proportional to their diameters; and as their lengths ought to be in proportion to their charges, and they are proportional to the diameters of their ſhot, the length muſt therefore likewiſe be proportional to the diameters of their ſhot.

We have likewiſe proved in the ſame page, that the greateſt velocities of projected bodies have certain limits which they cannot exceed, let the force that acts upon them be what it will; which confirms that part of the experiments with reſpect to the beſt charge.

Now ſince the greateſt velocities of projected bodies are proportional to their diameters, the largeſt caliber will therefore carry their ſhot fartheſt. Conſequently, the queſtion of finding the length of a piece, ſo as to produce the greateſt range, depends on its caliber, its length, and on its charge, which we have here determined.

As theſe experiments are the beſt and only ones that ever were made on Artillery, as far as I have ſeen or know, and agree exactly with the theory we have given in the appendix, ſo we may affirm this theory to be the beſt and only one grounded upon true and unexceptional principles, and that all others hitherto publiſhed are without

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without foundation; and therefore all the concluſions drawn from them erroneous.

Though it may be convenient on ſome particular occaſion to have guns which carry their ſhot as far as poſſible, yet in common practice this rule is not to be followed; for on board of ſhips theſe long and heavy guns would not anſwer ſo well as ſhorter and lighter, becauſe ſhort guns are eaſier loaded, require leſs room for the recoil, and are more expeditious in action; and ſince ſhips come ſo near together in action as they do at preſent, the long ranges are intirely uſeleſs: beſides, the charge of half the weight of the ſhot is too much, and ought never to be uſed, one third at moſt is quite ſufficient, and perhaps leſs, does more execution, and heat the guns leſs: all theſe advantages ought not to be neglected.

The length of battering pieces ought to be ſuch, as to enter into the embraſures ſo far, as that the blaſt of exploſion does not deſtroy them in a day's firing; in that caſe they may be repaired again at night, becauſe it is impoſſible to prevent the effect of the blaſt intirely: for which reaſon all calibers, not exceeding a 24 pounder, may be 21 diameters long, but thoſe above cannot be ſo long without inconveniencies; but the charges ſhould never exceed one third of the ſhot's weight, becauſe it has been found by experience that this charge is ſufficient, and perhaps leſs would be better.

It muſt be obſerved, that guns ſhould never be loaded with more powder than is juſt ſufficient to produce the deſired effect, which a ſkilful commander can or may always diſcover in practice; by which the guns will not be heated more than is neceſſary, and they may be fired longer without receiving much damage.

What has been ſaid in reſpect to battering pieces may be applied to garriſon ones; only the beſt charges may be given them on particular occaſions, as at the beginning of an attack to oblige the enemy to begin his approaches as far as poſſible, or in a place ſituated near

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the ſea or a navigable river, to prevent ſhips from coming too near.

The field pieces ſhould have the beſt length and charges, in order to annoy the enemy at the greateſt diſtance, excepting the battalion guns, which ſhould be ſhort and light, that they may advance as well as retire as quick as the army. From whence follows this

General RULE,

That the length of guns ought to be determined from their particular uſes.

Thickneſs of METAL.

It is an univerſal cuſtom in *Europe* to make the guns with reinforces; that is, they are, as it were, made of three fruſtrums of cones joined together, ſo as the leaſt baſe of the former is always greater than the greateſt of the ſucceeding one, whereby the metal breaks off in two places on a ſudden, as the reader has ſeen in the conſtruction of pieces given here before. But ſince powder acts uniformly and not by ſtarts, it is hard to judge from whence this ridiculous cuſtom has ariſen, which ſeems to be as old as the invention of guns; and nothing but the ignorance of the effects of powder has been the cauſe of its being handed down to our time. Our veneration for old cuſtoms is ſo great, that whoever attempts to make any change is looked upon with contempt, let his reaſons be ever ſo plain and good; this I know too well by experience.

Yet I ſhall freely communicate whatever I think to be an improvement and uſeful to the public; let the conſequence be what it will, I ſhall do my duty. Since then powder acts gradually and not by ſtarts, there ſhould be no breakings off in the metal; and we have ſhewn in the remark after Theor. IV. that the piece ſhould be cylindric, from the baſe ring to the end of the

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the charge, and from thence, by the nature of the exploſion, a curve line bending inwards quite to the mouth of the piece: but as the conſtruction of the curve is not very eaſy, and differs in the main but very little from a right line, by making the part between the end of the charge and the mouth conical, it will be ſufficiently exact for practice.

When pieces were loaded with two thirds of their ſhots weight, the thickneſs of metal was then at the vent equal to the diameter of the ſhot; but ſince there is no occaſion to load pieces with more than half that weight, the thickneſs of metal ought to be leſs; for which reaſon the preſent light 6 pounders are only the two thirds of the diameter of the ſhot thick, and their length 15 diameters; the ſame thickneſs is given to the 24 pounders, and their length is but 12 diameters; and as this thickneſs has been found ſufficient by many trials, when the charge and length remain the ſame, there is no reaſon to make them ſtronger.

The ſtrength given to iron guns is certainly more than required, ſuppoſing the charge no more than one third of the ſhot's weight; this has been found true by ſome, whoſe thickneſs at the vent was equal to the diameter of the ſhot, and half that thickneſs at the mouth.

VENT.

The common method of placing the vent is within about a quarter of an inch from the bottom of the chamber or bore: yet it is imagined, that if the vent was to come out at the middle of the charge, the powder would be inflamed in leſs time than in any other caſe. But notwithſtanding that this appears ſo viſible, and ſeems to be demonſtrable, yet I have found the contrary, to the great ſurprize of the ſpectators. I had two mortars, the chamber of one cylindric, the diameter of the baſe one inch, and the axis two; the chamber of the other

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concave; each of these chambers had two vents, one at the bottom, and the other in the middle, and contrived in such a manner, that one could be screwed up, whilst the other served to fire; and I found always the range of the shell greater, when the lower vent was used, than when the powder was fired by the middle one. The same thing was tried by colonel *Desaguliers* and me, with different cylindric chambers, some of which were three or four times the diameter of the base in length.

This being fact, it remains now to know, whether the same would do in mortars of a larger size, or in guns; for I must own, that after these trials, and some others of a still more extraordinary nature, which have been mentioned in the introduction, I can scarcely believe any thing relating to the effect of gunpowder, but what has been found true by a sufficient number of experiments.

Bore.

The windage, or difference between the diameters of the shot and the bore, is not the same in *England* as abroad. Suppose the diameter of a shot divided into 20 equal parts, then the diameter of the bore is 21 of these parts; the *French* suppose the diameter of the shot divided into 26 parts, and the diameter of the bore to be 27; what the proportion is in *Holland* and other parts of *Germany* I do not know; but it is evident, that the less windage there is, the truer the shot will go; and having less room to bounce from one side to another, the gun will not be spoiled so soon; for which reason I suppose, in the following constructions, the diameter of the shot to be divided into 24 equal parts, and make the bore 25, which is a medium between the *English* and *French* method. This we do not so much in order to differ from others, as on account of the convenient scale it affords, to construct not only guns thereby, but also their carriages, as will be seen hereafter.

The

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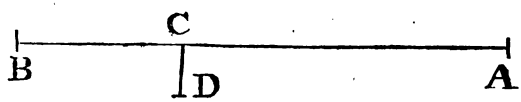
The *French* make little chambers in their 16 and 24 pounders, of one third of a caliber long, and as much in diameter; by this means they ſay the metal becomes thicker at the vent, and prevents its ſpoiling ſo ſoon. But as chambers are much more advantageous in other reſpects, we ſhall conſtruct ſome hereafter, ſo as to have all the advantages that can be had.

Some are for making the bottoms of the bore conical, others ſpherical; and laſtly, ſome quite flat; but I can find no reaſon to prefer one way before another, excepting the conveniency there may be in adapting the cartridges in a more eaſy manner to their form.

TRUNNIONS.

The method of placing the trunnions ſo that their axis touches the lower ſurface of the bore, as is practiſed all over *Europe*, is ſo abſurd, that it is amazing no author or artiſt has thought proper to change it; the only reaſon I ever heard given for this practice, was, that by this means they were ſtronger fixed to the gun, and of conſequence would not break off ſo ſoon as in any other place. As inſignificant as this reaſon is, it ſerves however to defend that old eſtabliſhed cuſtom.



But to ſhew the abſurdity of it; ſuppoſe A B to repreſent the center line of the bore, and C D the diſtance of the center line of the trunnions from that of the bore. Now becauſe when the piece is fired, the exploſion acts againſt the breech B, and makes the piece recoil, but being fixed to the carriage by the trunnions, endeavours to turn about the point D, whereby it preſſes alſo upon the coins under the breech B, where they by their elaſti-

city

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city repel it upwards, and its weight brings it down again. The piece therefore acquires a pendulous motion about the center D, which cauſes the coins to fly off, changes its direction, and ſhakes the carriage with great violence, and often breaks it to pieces.

In long pieces this effect is not ſo ſenſible as in ſhort ones; and though carriages generally break in their centers, yet the cauſe has never been attributed to the wrong ſituation of the trunnions; not even after the many accidents of that kind which have happened lately: for a ſhort and light 24 pounder was tried at *Woolwich*, to know whether they might not be as uſeful in action as the light 6 pounders; but every time it was fired, it broke its carriage to pieces. From theſe accidents, and its recoiling more than the heavy pieces, they were rejected as uſeleſs, without thinking in the leaſt that both inconveniencies might eaſily be remedied.

The piece ſtood upon a platform of ſtone quite level, which is not, nor ever has been, practiſed on any occaſion whatever; for in the field they are placed upon the rough ground without any platform; and as the recoil is never ſo great in ſuch a ſituation, as upon a level ſtone platform, this objection is to no purpoſe: and that this is fact beyond diſpute, appears from the trials made at the ſame time with light 6 pounders, which recoiled likewiſe in an extraordinary manner, notwithſtanding they are found in real ſervice not to do ſo.

In a ſiege, when batteries are erected, the platforms are made of wooden planks, raiſed behind, more or leſs, according as it is neceſſary, to prevent the pieces from recoiling farther than is convenient to reload them. And ſince this may be done at pleaſure, without the leaſt inconvenience, the rejecting them on that account is frivolous and abſurd.

To prevent theſe pieces from breaking their carriages is eaſy, if we dare break through old cuſtoms, by making the axis of the trunnions to paſs through the center line of the bore, as may be ſeen in our conſtructions

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tions hereafter. The pretence of their breaking off from the piece is taken away, by making ſhoulders to them; beſides, this objection is only imaginary, ſince it has never been tried.

What we have ſaid upon this head is likewiſe confirmed by practice in howitzes, which, being fixed to their carriages in the ſame manner as guns, are properly nothing elſe than ſhort guns with chambers; for their trunnions are placed in the manner we propoſe, and, when fired, acquire no other motion than a backward one, without ſhaking in the leaſt the carriage, nor did their trunnions ever ſuffer.

Mouldings.

As they are made by way of ornament only, they depend chiefly on the maker's fancy; it muſt however be obſerved, that they ſhould be plain and ſimple, and ſuch as are uſed in architecture, from whence they have been borrowed; the metal ſhould be projected as little as can be, that the piece may lie cloſe on the carriage: the mouldings of our mortars are oddly jumbled together, without any order or judgment; and thoſe of our iron guns are more numerous than is conſiſtent with reaſon, for they have fillets on both ſides the firſt and ſecond reinforce rings, which are not uſed in braſs pieces; and as theſe mouldings are not turned in iron, they appear ridiculous, and more ſo in ſwivel guns, which have as many as thoſe of the largeſt caliber.

Muzzle.

The ſwelling of the metal at the muzzle ſeems to have been made merely to make the pieces look graceful, or perhaps to appear of a larger caliber to an enemy at a diſtance than they really are. When they are too heavy, the piece is liable to bend at the neck when heated with much firing, which makes it either break

or

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or bend, and ſo become uſeleſs. Some are of opinion, that the metal ſhould be as high at the muzzle as at the baſe ring, that the viſual ray over the metal may be parallel to the center line of the bore, which they imagine to be neceſſary for laying or pointing the piece in a proper manner; but thoſe who are for this practice are very little acquainted with real ſervice: for as the ſhot deſcends in its flight by the force of gravity, the piece muſt be laid higher than the object to be hit; ſo that when the metal is equally high before and behind, the object is hid intirely by the thickneſs of the metal, and conſequently the piece can never be laid true; whereas if the height of the metal be leſs at the muzzle than at the breech, the elevation of the piece, when pointed at the object, will anſwer the deſcent of the ſhot at a certain diſtance, and the ſkill of the gunner will be ſufficient to make a proper allowance when the object is either farther or nearer.

CASCABLE.

They are made of various figures; ſometimes like a bunch of grapes, or as the heads of different kinds of animals: the *French* diſtinguiſh their calibers by the different forms of the caſcables; but as this is expenſive when they are well carved, and looks paltry when not well done, the manner of making them quite plain, with a button and a few breech mouldings, as we do here, ſeems in my opinion much neater, and is leſs expenſive. It is true, that the diſtinguiſhing the different calibers is very proper; but this may be done in another manner, more agreeable to the ſight, and cheaper.

Line of Direction.

Formerly pieces were made with a cavity upon the baſe ring, and a button upon the higheſt part of the muzzle, whereby they were directed in the ſame manner as

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as fowling-pieces are; but how this line came to be left off in latter times I cannot tell; for to find the center line of a piece every time it is to be fired with a plummet or an inſtrument, as is the cuſtom, is very tedious, uncertain, and unmaſterly: for as it is impoſſible to turn the outſide of a piece true to the bore, conſidering the bluntneſs of the tools and the heavineſs of the engine, the center line can never be found to any tolerable degree of exactneſs, by an inſtrument applied on the outſide of a piece; and when the ſhot does not hit the mark, the gunner is at a loſs to know, whether it is owing to his want of ſkill, or to this line not being rightly marked; whereby it is impoſſible he ſhould be able to form a right judgment how to direct the piece.

But when the line of direction is marked on the piece in the aforeſaid manner, and the ſhot does not hit the mark, he knows how to rectify the miſtake, becauſe the line remains always the ſame, whether it be marked right or not, which I have ſeen many times. It is ſaid, that the platforms are never rightly level, and if one wheel of the carriage ſtands higher than the other, the line of direction becomes uſeleſs; but I can find no reaſon for not laying the planks level when the platform is made, ſince I always have ſeen a level uſed; and this may even be done ſufficiently exact by the eye without a level, ſince a ſmall trifle, either on one ſide or other, cannot cauſe any great error in the laying of the piece; and in a field engagement, where no batteries are made, it is of no ſignification, whether the piece points a little to the right or left, provided it is not too high or too low.

CALIBERS.

The choice of calibers depends on two conſiderations, *viz.* they ſhould never be leſs than thoſe of other nations; becauſe in an engagement by land or ſea, the larger ſhot have always the advantage; and their diameters

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meters ſhould have a ſenſible difference to diſtinguiſh their ſhot with eaſe; otherwiſe it may happen in an engagement, when men are generally in ſome confuſion, that the one will be taken for the other, as has happened to my knowledge, whereby the piece becomes unſerviceable, till the ſhot ſticking in it, has been blown out again; which ſometimes cannot be done without rendering the piece unſerviceable.

As the conſtruction of pieces, as well as that of their carriages, ought to depend on the diameter of their ſhot, methinks they ſhould be expreſſed by whole numbers as much as can be, or at leaſt by ſome eaſy fractions. Thus they ſhould be expreſſed by 3; 3.5; 4; 4.5; 5; 5.5; 6 inches; which anſwer nearly to a 4, 6, 9, 13, 18, 24, and 31 pounders. And as the diameter of a 9 pound ball is 4 inches, and may ſerve in a manner as a ſtandard to make the reſt by, I am ſorry to ſee that this caliber has been rejected lately in braſs cannon.

This is what we thought neceſſary to premiſe before we enter upon the conſtruction of pieces, to ſatisfy the reader, that they are the reſult of a well aſſerted theory, and of ſuch reaſons as ought to be well conſidered beforehand; but whether they will ſatisfy artiſts prejudiced in favour of the moſt abſurd, old eſtabliſhed cuſtoms, is what time will ſhew: the ſubject is of ſo great an importance to the nation, that it deſerves to be well examined beforehand, and proper experiments made before any change is introduced; for which reaſon I ſubmit theſe my endeavours to ſerve the public to the judgment of my ſuperiors.

General CONSTRUCTION *for braſs battering pieces.*

Plate I. Fig. 1.

Let the length A B, of the piece, be 18 diameters of the ſhot; divide that diameter in 24 equal parts for a

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ſcale, whereby all the reſt of the dimenſions are determined. Make the diameter of the bore equal to 25 of theſe parts; from the hind part A of the baſe ring, to the fore part D of the vent aſtragal ſet off 40 parts; make the thickneſs of metal taken from the bore at A and D, equal to 18 parts, that is, three quarters of the ſhot's diameter, and 9 parts, or half that thickneſs at the mouth; then the lines drawn through theſe points will determine the figure of the gun, which therefore is cylindric from A to D, and conical from thence to the mouth.

The center line of the trunnions croſſes the center line of the bore at right angles, and at a diſtance of three ſevenths of the total length A B of the gun, from the hind part A of the breech; their diameter is 18 parts, as well as their length, free from the projection of the ſecond reinforce ring; the ſecond reinforce E F, is always two thirds of the firſt A E; the breech A C is 16 parts, the chace girdle F I, 14; the muzzle H B, the tenth part of the total length of the gun, which is here 43 parts, and the diameter of the ſwelling, m, of the muzle is 6 parts diſtant from the mouth.

The breadth of the baſe ring and ogee next to it are each 6 parts; the firſt and ſecond reinforce rings, and the ogees next to them, 5, the aſtragals and fillets 4; the cavetto at the mouth 2.5, and the fillets one each.

The baſe ring projects the metal by two parts, the firſt and ſecond reinforce rings by one, or rather leſs; the fillets of the aſtragals by one half, and the round part is deſcribed from a center placed in the outline of the piece. There is a circular ſhoulder about the trunnions, whoſe diameter exceeds that of the trunnions by 6 parts, and projects even with the ſecond reinforce ring.

CAS-

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CASCABLE. Fig. 2.

The diſtance from the hind part A, of the baſe ring, to the center C, of the button, is 27 parts, the radius of the button 9, the breadth of the quarter round 2, the ogee 5, and the fillets one each. From the center C of the button, draw lines to the extremity of the baſe ring E, F, in which find the center O, ſo as the arc deſcribed meets the arc of the button in the line C F, and touches the ſecond fillet: theſe arcs will determine the neck; the line O p, drawn through the center O, parallel to C A, will determine the ſecond fillet, and C F, the firſt.

To deſcribe the ogee, join the extremities n, q, of the fillets; through the point q, draw the line r p, parallel to O n, produced; in theſe two lines find the centers p, ſo as the arcs deſcribed through the points n q, meet in the middle of the line n q: the arc which determines the quarter round, is deſcribed from a center r, in p, q, produced ſo as to meet the extremity F, of the baſe ring within one part. The ſhell is 6 parts broad, and the diameter of the vent a fifth part of an inch.

MUZZLE. Fig. 3.

Take the line B K, equal to twenty parts, and erect the perpendicular I K, after having made L P, equal to 6 parts, the center I, is to be found ſo as the arc deſcribed, through the point K, ſhall meet the point L; and if through the point a, at 4 parts diſtant from H B, the line a r, be drawn perpendicular to L P, the center r, is to be found ſo as the arc deſcribed through the point L, may meet the extremity of the fillet a. The cavetto is no more than a concave quarter round.

It has been found by experiments, that when pieces have chambers, they require a leſs charge than they would do otherwiſe; for which reaſon I would make a chamber in all Pieces of 24 pound ball and upwards, whoſe diameter ſhould be two thirds the diameter of the bore,

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bore, and length equal to that diameter; ſuch as is repreſented in the firſt figure. Although this chamber contains but one ninth part of the ſhot's weight of powder, yet the effect it produces is nearly equal to that of a fourth part; which is ſufficient in large pieces.

Whatever faults there may be found with the particulars of this and the following conſtructions, it cannot, however, be denied but this is the true method whereby artillery pieces ſhould be made; for ſince architecture has its certain rules whereby to conſtruct the ſeveral parts of a column from its diameter, there is no reaſon why the parts of a piece ſhould not be determined in the ſame manner.

To find the weight of metal.

The ſquare of 43, the diameter of the muzzle without mouldings,	1849
The ſquare of 61, the diameter at the vent aſtragal,	3731
The rectangle, or main plan of theſe diameters, 43 and 61,	2623
The ſum of theſe three products added,	8193
Which multiplied by one third of 392, the length D B,	1070552
The ſquare of the diameter 61, multiplied by 40, the length A D,	148840
Four times the cube of 18, for the trunions, caſcable, and mould,	23328
The ſum of theſe laſt three products added,	1242720
The ſquare of the bore 25, multiplied by its length 416,	260000
The difference between theſe two laſt ſums,	982720
The ſquare of the diameter is to the area of the circle, as 452 to 355,	771826

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These are cubic parts of the shot's diameter, divided into 24 equal parts: and as a cubic foot of gun metal weighs 459 pounds, according to our tables, or 192 cubic inches 61 pounds; the last sum reduced in this proportion gives 245215.

But the cube of 24, the diameter of the shot, is to the cube of 4, the diameter of a 9 pound ball, as 216 to unity, so is 245215 to 1135 pounds, the weight of a 9 pounder; and if this number be divided by 9, we shall have 126 pounds of metal for every pound of the shot's weight. Consequently the weight of the shot of any gun, according to this construction, multiplied by 126, and the product divided by 112, gives the weight of the gun.

Length and weight of battering pieces.

Old Pieces.

Calib.	Length.	Weight.
6	8 : 0	19 : 0 : 0
9	9 : 0	25 : 0 : 0
12	9 : 0	29 : 0 : 0
18	9 : 6	48 : 0 : 0
24	9 : 6	51 : 0 : 0
32	10 : 0	55 : 2 : 7
42	9 : 6	61 : 2 : 10

New Pieces.

Calib.	Length.	Weight.
12	6 : 7	13 : 2 : 0
18	7 : 6	20 : 1 : 0
24	8 : 4	27 : 0 : 0
32	9 : 2	36 : 0 : 0
36	9 : 6	40 : 2 : 0
42	10 : 0	47 : 1 : 0
48	10 : 6	54 : 0 : 0

The lengths of pieces are in feet and inches; old guns of the same caliber are not always of the same length, nor of the same weight; these given here are those most commonly used at present; but for what reason the 32 pounder is longer than the 42 is only known to the maker.

Remarks

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Remarks on this conſtruction.

We have ſhewn in the Introduction, that the guns ſhould be cylindric as far as the charge reaches, and from thence conical to the mouth; and therefore the conſtruction is conformable to the theory: we have likewiſe ſhewn, that the center line of the trunions ought to paſs through the center line of the bore; for when it is lower, as has hitherto been the cuſtom, the carriages are deſtroyed in a ſhort time; the diſtance of the trunions from the breech is the ſame in both, and we found it likewiſe to be right by computation: the length of the 36 and 42 pounders is agreeable to that commonly given to battering pieces; and ſince both theſe calibers weigh leſs than the old 24 pounders, they may be uſed inſtead thereof, as well as the 48 pounder, which weighs very little more than ſome 24 pounders, eſpecially as a breach is much ſooner made by large calibers than by ſmall ones; and that they are ſtrong enough we are certain, ſince our preſent field-pieces, whoſe ſtrength is to that of theſe in the proportion of 8 to 9, have been found by repeated experiments, to bear any firing whatever; and they need not be loaded but with one fourth of the ſhot's weight, when they are made without chambers, ſince the force of a 32 pounder, loaded with 8 pounds of powder, is greater than that of a 24 pounder loaded with 8 pounds, in the proportion of the weights of their ſhot; that is, in proportion of 4 to 3; and the force of a higher caliber is ſtill greater.

It is true that theſe new pieces would recoil more than the old, if they were loaded with the ſame charges, which is not the caſe; beſides, it may be eaſily prevented, by allowing a greater ſlope to the platform. Conſequently the pieces, according to this conſtruction, have greatly the advantage over the old ones.

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Conſtruction of iron battering and garriſon pieces.

Let the length A B be 21 diameters of the ſhot, divide that diameter into 24 equal parts as before, make the diameter of the bore 25; from the hind part A of the baſe ring, to the fore part D of the vent aſtragal, ſet off 48 parts; make the thickneſs of the metal, taken from the bore at A and D, equal to 25 parts, and 12 at the mouth B.

The center line of the trunions croſſes the center line of the bore at right angles, at the diſtance of three ſeventhes of the total length of the gun, that is nine diameters from the hind part A of the breech: their diameter is 24 parts, as well as their length, free from the progreſſion of the ſecond reinforce ring; the firſt reinforce 9 diameters and 3 parts; the ſecond 5 diameters and 9 parts; the breech A C, 24 parts; the muzzle H B, 50; the chace girdle F I, 16; the diameter of the ſwelling at the muzzle is 6 parts diſtant from the mouth; and the reſt as before.

By the ſame manner of computation as before, I find two hundred weight of metal for every pound of the ſhot's weight. Hence we have the following,

Iron battering and garriſon pieces.

Caliber.	Length.	Weight.
3	4 : 10	6 : 0 : 0
4	5 : 4	8 : 0 : 0
6	6 : 1	12 : 0 : 0
9	7 : 0	18 : 0 : 0
12	7 : 8	24 : 0 : 0
18	9 : 0	36 : 0 : 0
24	9 : 8	48 : 0 : 0
32	9 : 8	56 : 0 : 0

Obſerve,

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Obſerve, that the 32 pounder is but 19 diameters long; the thickneſs of metal at the breech 24, and 11 at the muzzle. Experience has ſufficiently ſhewn in this laſt war, that iron guns ſtand much better, in making a breach, than the braſs; for the latter have failed in all the ſieges they were uſed.

I can affirm, that a hundred and a half of metal is ſufficient for one ponnd of the ſhot's weight, provided the guns are made of good virgin ore: and one ſhould think it would be the intereſt of the nation, to make uſe of the beſt that is to be found in the country for that purpoſe.

Beſides, a ſet of 6, 7, 12, 18, 24, 32 of braſs pieces, weigh 22700 weight, which, at 130 *l. per* ton, coſt 1475 *l.* 10 *s.* and the ſame ſet of iron weighs 19400, a ton coſts 16 *l.* and the whole ſet 155 *l.* 4 *s.* So that 9 ſets of iron coſt no more than one of braſs.

Conſtruction of braſs pieces for ſhips.

As long guns are very inconvenient on board of ſhips on account of the difficulty in loading them, we ſhall ſuppoſe the length A B to be 15 diameters of the ſhot, which diameter being divided into 24 equal parts, as before, and the diameter of the bore being likewiſe 25 parts; the diſtance AD is 40 parts; the breech AC 18; the thickneſs of the metal at A and D is 20, and 10 at the mouth B; the reſt of the conſtruction is the ſame as before; only the diameter and length of the trunions are 20 parts each.

By the ſame manner of computing the weight of metal as before, we ſhall have 124 pounds of metal for every pound of the ſhot's weight; which gives the following table.

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Braſs ſhip-guns.

Caliber.	Length.	Weight.
3	3 : 6	3 : 1 : 17
6	4 : 4	6 : 2 : 14
9	5 : 0	10 : 0 : 0
12	5 : 6	13 : 1 : 3
18	6 : 4	20 : 0 : 0
24	7 : 0	26 : 2 : 7
32	7 : 6	35 : 1 : 17
36	7 : 10	40 : 0 : 0
42	8 : 4	46 : 2 : 0
48	8 : 6	53 : 0 : 14

Remarks on this conſtruction.

In this conſtruction we have not conſidered the ſtrength ſo much as the weight, on account of the recoil; for ſhould that be too great it might be attended with great inconveniency, ſuch as tearing the tackle. But when theſe guns are loaded with one fourth of the ſhot's weight, if there are no chambers made, the recoil will be but little greater, or perhaps no more than that of old guns loaded with half of the ſhot's weight: this being the caſe, there is not the leaſt reaſon to make pieces ſo heavy as at preſent, nor ſo long: for if it be conſidered that ſhips may carry 12, 18, 24, 36, 42, 48 pounders of this new conſtruction, inſtead of 6, 9, 12, 18, 24, and 32 pounders of the preſent, and at the ſame time carry leſs burthen; it muſt appear to every rational perſon, what advantage ſuch a ſhip muſt have above an

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enemy's of the ſame rate. To illuſtrate this by an example, we ſhall give here a liſt of the guns, length and weight, which are on board the *Royal George*.

Pr.	Num.	Length.	Weight.	Total.
42	28	9 : 6	61 ; 2 : 10	1820
24	28	9 : 6	51 : 0 : 0	1428
12	28	9 : 0	29 : 0 : 0	812
6	16	8 : 0	19 : 0 : 0	304

Total 4366 or 218.3 tons.

A new ſet of guns.

Pr.	Num.	Length.	Weight.	Total.
42	28	8 : 4	46 : 2 0	1302 : 0 : 0
32	28	7 : 6	35 : 1 17	991 : 3 : 1
24	28	7 : 0	26 : 2 7	743 : 3 : 21
18	16	6 : 4	20 : 0 0	320 : 0 : 0

Total —— 3357 : 2 : 22
Total in tons — 167.8
Difference — — 50.5

It muſt be obſerved, that inſtead of 28 pieces of 42 pounders (formerly taken from the *French*) which are at preſent on board, the ſame number of ours are to be put in their place.

Hence it appears, notwithſtanding, that there are 28 pieces of 32 pounders in the new liſt, inſtead of 28 twelve pounders, and 16 eighteen pounders inſtead of the ſame number of ſixes; yet the difference between the total weights is 50.5 tons, an object too conſiderable not to be obſerved. Beſides, the new guns being ſhorter than the old, they may be fired much faſter.

That the ſtrength of theſe guns is ſufficient appears from the trial of 2 twelve pounders made for admiral *Keppel*; they were loaded with 12 pounds of powder each

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time, and ſtood the proof, without receiving any damage; and I may venture to ſay, that they would ſtand any number of firings with the common charge.

General conſtruction for iron ſhip guns.

Let the length of the piece be 15 diameters of the ſhot; the diameter of the bore 25 parts of the ſhot's diameter divided into 24, as before; the diſtance A D, 40 parts; the breech A C, 24; the thickneſs of metal at the vent 24, and half that thickneſs at the mouth; the diameter and length of the trunions 24 each, and the reſt of the conſtruction the ſame as before.

By the ſame way of computing as before, we ſhall find 140 pounds of iron, or a hundred and a quarter, for every pound weight of the ſhot: ſuppoſing that 108 cubic inches of caſt iron weigh 29 pounds, according to our table of ſpecific gravities.

Iron ſhip guns.

Old pieces.

Calib.	Length.	Weight.
3	4 : 6	7 : 1 : 7
4	6 : 0	12 : 2 : 13
6	7 : 0	17 : 1 : 14
9	7 : 0	23 : 2 : 2
12	9 : 0	32 : 3 : 3
18	9 : 0	41 : 1 : 8
24	9 : 0	48 : 0 : 0
32	9 : 6	53 : 3 : 23
42	10 : 0	55 : 1 : 12

New pieces.

Calib.	Length.	Weight.
3	3 : 6	3 : 3 : 0
6	4 : 4	7 : 2 : 0
9	5 : 0	11 : 1 : 0
12	5 : 6	15 : 0 : 0
18	6 : 4	22 : 2 : 0
24	7 : 0	30 : 0 : 0
32	7 : 6	40 : 0 : 0
42	8 : 4	52 : 2 : 0
48	8 : 6	60 : 0 : 0

Remarks

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Remarks on this conſtruction.

The making iron pieces in ſuch a manner as not to be heavier than is neceſſary, nor yet too weak, ſo as to be in any danger to break when fired briſkly for ſome time, is of the greateſt importance, inſomuch as all our ſhips, one or two excepted, are provided therewith; for by making them too heavy the ſhips cannot carry ſo many large large calibers as they otherwiſe might, which is agreed by the beſt judges to be a great diſadvantage; if, on the other hand, they ſhould be ſo weak as not to bear a briſk firing, the burſting of a piece in an action might create ſuch a confuſion as to cauſe the loſs of the ſhip. But to prove beyond doubt that no danger can be apprehended from guns made according to this conſtruction, provided the iron is good (ſuch as that of the *Carron* company) appears from the trial of 2 three pounders made for lord *Egmont*; for they both ſtood the ordnance proof loaded with three pounds of powder, and I am certain they would have ſtood if they had been loaded with double that charge. There was alſo made 2 ſix and 2 twelve pounders for Monſ. *De Malo*, the *Portugueſe* envoy; and they ſtood their proof, and would have done it, if they had been loaded with much greater charges than the weight of their ſhot. Now ſince all the calibers are proportionally ſtrong, according to their charges, the one being found ſtrong enough by practice, all the reſt muſt be ſo too. Secondly, we have a great many 6 and 9 pounders that were caſt formerly, and which have been uſed a great while, and are leſs thick at the muzzle aſtragal than the new ones: this being an undeniable fact, proves again, that the new are of a proper ſtrength. The reaſon that the preſent guns are ſo much heavier than the new, is owing to their greater length; beſides the charges of powder have hitherto been greater than was neceſſary, and the ſtrength of the pieces has, or ought to have been

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been made in proportion. With regard to the length of theſe new pieces, they are ſuch as are conceived by ſome of the beſt ſea officers to be much more convenient than if they were longer, on account of the rope rammer they are obliged to uſe; for in long pieces, if the rope is hard and ſtiff, it is bent with great difficulty, and if not, will ſcarcely ſuffice to ram the ſhot home.

Guns of a new conſtruction uſed in the ſeveral men of war.

Num. of guns.	Weight of old.	Weight of new.	Num. of ſhips.	Weight of old number.	Weight of the new number.
100	4367. 3	2556. 0	5	21838. 3	12780
90	3537. 3	2001. 0	9	31839. 3	18009
80	3108. 3	1827. 0	7	21761. 1	12789
74	3091. 0	1840. 2	32	98912. 0	58896
70	2997. 0	1796. 2	10	29970. 0	17965
64	2543. 3	1305. 0	23	58506. 1	30015
60	2177. 3	1185. 0	30	65332. 2	35550
50	1881. 1	1035. 0	19	35743. 3	19665
44	1365. 2	705. 0	8	10924. 0	5640
40	1234. 2	312. 2	9	11110. 2	2812
36	963. 3	450. 0	7	6746. 1	3150
32	956. 2	435. 0	28	26782. 0	12180
28	593. 2	285. 0	23	13650. 1	6555
24	531. 3	255. 0	12	6381. 0	3060
20	421. 2	191. 1	15	6322. 2	2869

Total of the Weights —— —— 445820 : 241935
Difference —— —— —— 203885 00 or 101944½ tons.
Difference of the expences——1631081.

If to this we add the difference 26321 l. between the braſs guns of the *Royal George* and the ſame ſet of iron, we get 189429 *l.* for the difference between the expences of the old and new ſet. And if the number of guns on board of the ſloops and thoſe in the garriſons, as well as thoſe which ſerve in the field, it may perhaps amount to as much more.

Hence

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Hence every ſhip may carry very nearly double calibers of theſe new guns to thoſe of the old ones, and that with ſafety, and be leſs burthened at the ſame time, as has been fully proved: the great advantage of ſuch a change muſt be plain to all ſuch as are concerned in naval affairs. I muſt obſerve one thing more, that the ſmall charge we propoſe may appear inſufficient in calibers under a 24 pounder; but when it is conſidered, that when ſhips come to a proper diſtance, the ſmall ſhots have as much chance to penetrate the ſhip as the large, though their effect is leſs in proportion; but at a great diſtance the reſiſtance of the air is greater in proportion as the diameter diminiſhes, as Mr. *Robins* has rightly obſerved.

But as all commanders make, or ought to make a point of it, to come cloſe to an enemy before they begin to fire, there is no reaſon to fear but that theſe ſmall calibers are as uſeful as any others.

Number

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Number and caliber of guns on board the ſeveral men of war.

Old Eſtabliſhment.

N°	42	32	24	18	12	9	6	4
100	28		28		28		16	
90		26		26	26		12	
80		26		26		24	4	
74		28		28		18		
70		28		28		14		
64			26		26	12		
60			24		26		10	
50			22		22		6	
44				20		20	4	
40				20		20		
36					26		10	
32					26		6	
28						24		4
24						22		2
20					10		10	

New Eſtabliſhment propoſed.

N°	48	42	32	24	18	12	9	6
100	28		28	28		16		
90		26	26	26		12		
80		26	26		24	4		
74		28	28		18			
70		28	28		4			
64			26	26	12			
60			24	26		10		
50			22	22		6		
44			20		20	4		
40			20		20	4		
36				26		10		
32				26		10		
28				24		4		
24				22			2	
20				10		10		

The firſt column contains the number of guns which the ſhips carry, according to the preſent eſtabliſhment; the numbers in the firſt horizontal line expreſs the calibers uſed on board of the men of war; and the number of each ſort are under them oppoſite the number the ſhips carry.

Conſtruction

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Conſtruction for light field pieces.

Let the length A B of the piece be 14 diameters, the diameter of the ſhot divided into 24, and the bore 25 as before; the thickneſs A C of the breech 14, the diſtance A D 39; the thickneſs of metal at the vent A D 16, and 8 at the mouth; the diameter and length of the trunions each 16 parts, and the reſt of the conſtruction as in the firſt.

A ring of metal is caſt under the caſcable in theſe light pieces, as is ſeen in figure the ſecond, which ſerves to faſten the head of a ſcrew, that is uſed inſtead of coins to raiſe the piece by: this ring is deſcribed from the ſame center, and with the ſame radius as the neck; the diameter of the hole to receive the bolt is 5 parts, and the thickneſs of the ring is 4 parts.

By the ſame way of computing the weight of metal as after the firſt conſtruction, we find about 85 pounds of metal for every pound of the ſhot's weight, which gives the following dimenſions.

FIELD PIECES.

Preſent.

Calib.	Length.	Weight.
3	3 : 6	2 : 3 : 10
6	4 : 6	4 : 3 : 10
12	5 : 0	8 : 3 : 8
24	5 : 6	16 : 3 : 13

New.

Calib.	Length.	Weight.
3	3 : 3	2 : 1 : 2
6	4 : 1	4 : 2 : 5
9	4 : 8	6 : 3 : 8
12	5 : 1	9 : 0 : 10
18	5 : 10	13 : 2 : 16
24	6 : 5	18 : 1 : 5

From

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From whence it appears, that the weights of the new conſtructed pieces nearly agree with thoſe uſed at preſent: the lengths of the 3 and 6 pounders new are leſs, and thoſe of 12 and 24 ſomething more than the lengths of the preſent. We have hitherto uſed but the four calibers marked above, and even the 12 and 24 very little, becauſe it has been found that theſe pieces, placed on a level platform, and loaded with one-fourth of the ſhot's weight of powder, recoil too much: yet as platforms are never made upon any occaſion without a ſlope, and in an engagement are placed upon turf, and the advantage of the ground is or may be taken, the firing theſe pieces upon a level platform made of ſtone is not an experiment to be depended upon.

Theſe light 18 and 24 pounders may ſerve in private expeditions for battering pieces, eſpecially where the road is very bad, and no heavy pieces can paſs, and yet battering pieces are required; which is the caſe where a fort or any other poſt is to be taken; for no leſs calibers are eſteemed ſufficient to make a breach, or induce the commander to ſurrender. There have been much lighter pieces made not many years ago, as a 6 pounder weighing but three hundred and a half, and which carried its ſhot very well with a pound and a quarter of powder; but it is imagined that they are attended with inconveniencies in real uſe, for which reaſon they have been rejected.

Conſtruction of iron garriſon pieces.

Let the length of theſe pieces be 18 diameters of the ſhot, and the reſt of the conſtruction be the ſame as that of iron ſhip guns: then by a like computation as before, we find $172\frac{2}{3}$ pounds of iron for every pound of the ſhot, and from thence we get the following dimenſions.

IRON

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IRON GARRISON PIECES.

Calib.	Length.	Weight.
3	4 : 2	4 : 2 : 12
6	5 : 3	9 : 1 : 0
9	6 : 0	13 : 3 : 12
12	6 : 7	18 : 2 : 0
18	7 : 6	27 : 3 : 0
24	8 : 4	37 : 0 : 0
32	9 : 2	49 : 2 : 18
42	10 : 0	64 : 0 : 0

As the 32 pounder weighs about the ſame, and is nearly the ſame length as the old 24 pounder, it may well ſerve upon the ſame occaſion. As to the lengths and weights of the other calibers, I imagine them ſuch as are proper for the uſes they are commonly applied to. The 42 pounder may alſo ſerve near the ſea, or in harbours, to prevent enemy's ſhips from paſſing by, with more advantage than 24 and 32 pounders, which are chiefly uſed at preſent upon thoſe occaſions.

But if ſome of the ſmaller calibers ſhould be thought too ſhort, according to the preſent practice, they may be lengthened ſo much as neceſſary, without changing any of the other dimenſions, which do not depend on the length.

Having given general conſtructions for the ſeveral ſorts of braſs and iron cannon, which are neceſſary upon different occaſions by land or ſea, in the moſt plain and eaſy

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eaſy manner we could think of (which none have yet done) and as theſe conſtructions are grounded on the moſt plauſible reaſons, ſupported by theory and practice, it is hoped our endeavours will be of uſe to the public, as expences are conſiderably leſſened. For if the great quantity of metal required in all the guns neceſſary to the nation, and the vaſt number of horſes now uſed in the field be conſidered, and that according to our conſtruction above one-third will be ſaved, as likewiſe a proportional number of horſes, one would imagine theſe advantages ſufficient to induce the directors of theſe affairs to examine well our ſcheme, and to make proper trials, in order to be convinced whether what is here propoſed is of any real advantage or not; at the ſame time guarding againſt the crafty inſinuations of ignorant artiſts, who find fault with improvements merely out of a ſelfiſh vanity, without judgment or knowledge.

As we propoſe to make chambers in all guns above an 18 pounder, it may be objected, that the difficulty of loading them will prevent their uſe; but as a rammer may be contrived ſo, as to load theſe pieces as eaſy as others, the only difference being to put the powder in cartridges, which is more than recompenſed by ſaving almoſt half of it; beſides, the pieces will not be heated ſo ſoon, and conſequently they may be fired much oftener without any danger of being damaged. When all theſe advantages are well conſidered, it will be found that chambers in large cannon is an improvement not to be neglected.

We muſt obſerve one thing more before we leave this ſubject, which is, that as we make the diameter of the bore but one 24th part larger than that of the ſhot (whereas the common practice is to make it one 20th part more) if the bores of the new conſtructed guns are made as uſual, they will be ſomething lighter than what we have marked them in the preceding tables. But as a ſhot goes much truer when it juſt fits the bore, and does leſs damage to the gun, by not bouncing from one ſide

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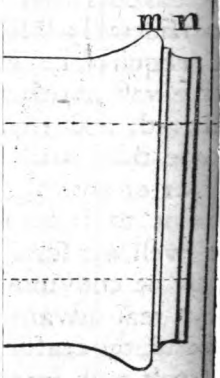
te. I B



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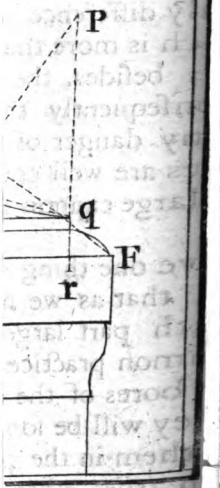


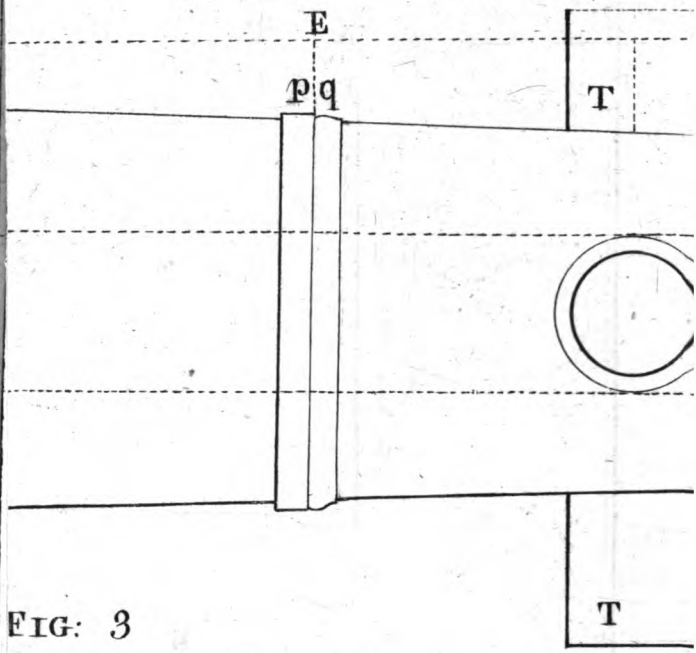
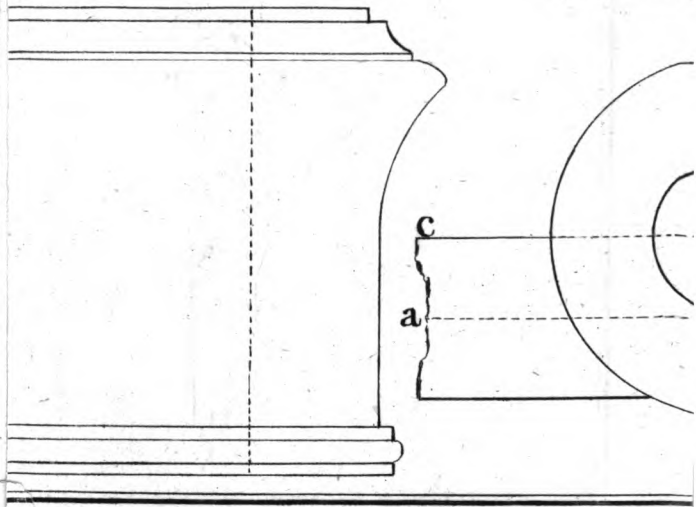


FIG: 3



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ſide to the other, it is to be hoped that they will be made in the manner we propoſe.

It is true that ſome artillery officers ſay, that the windage of a gun ſhould be equal to the thickneſs of the ladle; becauſe when it has been loaded for a while, the ſhot will not come out without being looſened thereby, in order to unload it; and when this cannot be done, it muſt be fired away, and ſo loſt; but as the windage of a 9 pounder, according to our conſtruction, is .166 of an inch, this is conceived a ſufficient thickneſs for a ladle, and thoſe of a higher caliber become ſtill thicker in proportion. But ſuppoſe this thickneſs is not ſufficient, the loſs of a ſhot is a mere trifle in reſpect to the advantage got thereby; beſides, as there is always a wad before the ſhot, I do not ſee that any duſt or dirt can get into the piece; and therefore when the muzzle is lowered, the ſhot will roll out of courſe.

There is another advantage in theſe general conſtructions, which is, that the diameters of the ſhots being marked on braſs rulers at full length, and divided into 24 equal parts, they will ſerve as ſcales to draw the draughts in full lengths for the uſe of the founders and the carriage-makers, whereby the patterns may be made with great eaſe and exactneſs.

PART III.

Conſtructions of MORTARS *and* HOWITZES.

MORTARS are a kind of ſhort cannon of a large bore, with chambers. Their uſe is to throw hollow balls filled with powder, called *ſhells*; which falling upon any building, or into the works of a fortification, burſt, and their fragments deſtroy every thing within reach. *Carcaſſes* are alſo thrown out of them, which are a ſort of ſhells with five holes, filled with

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pitch and other combuſtible matters, in order to ſet buildings on fire; and ſometimes baſkets full of ſtones, the ſize of a man's fiſt, are thrown from them upon an enemy, placed in the covert way in the time of a ſiege.

Mortars are diſtinguiſhed here chiefly by the diameter of the bore. For example, a ten inch mortar is that the diameter of whoſe bore is ten inches; there are however ſome ſmall ſorts, as coehorns and royals; the name of the firſt is derived from that of the inventor.

Sea mortars, or thoſe placed on board of ſhips, are longer and much heavier than the land. There is beſides another ſort, called howitzes, of a *German* invention, which differ from the former, in having their trunions placed nearly in the middle, and being mounted upon carriages like travelling gun-carriages.

PLATE II. Fig. 5.

The principal parts of a mortar are on the outſide the chaſe A, the reinforce B, the breech C, and the trunions D. In the inſide, the part where the ſhell is lodged, is the bore; and the part where the powder is lodged, called the chamber. The parts *n n*.

The figure of the chamber is made variouſly by different nations; the *Spaniards* uſe chiefly the ſpheric; the *French* the conic, cylindric, and the bottled or concave; the *Engliſh* make them in the form of a fruſtum of a cone. Each nation has its reaſons, good or bad, to prefer their make before that of others; but whoever conſiders theſe different forms in an impartial manner, and the reaſons given by authors for adhering to one preferable to others, will find, that nothing is leſs determined upon true principles or experiments, than the proportions of the ſeveral parts of a mortar; we ſhall therefore begin to give ſome tables of their dimenſions, and afterwards examine the different parts ſeparately, as we have done in guns, in order that the reader may diſtinguiſh their perfections and imperfections.

Dimenſions

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Dimenſions of the braſs land mortars now in uſe. Fig. 5.

Diameter of the bore	—	13	10	8	5.8	4.6
Total length of the mortar	—	44	33	25.5	16.5	13.5
From the mouth to the reinforce	—	15.25	10	8.5	4.75	4.2
Length of the reinforce	—	8.75	8.1	5	5	3.9
Length of the trunions from end to end		32.5	26	20	12	9.2
Diameter of the trunions	—	7.15	6.3	5	2.75	2.15
Length of the bore	—	24	18.	13	8.5	7
Length of the chamber	—	12	7.8	7.75	4.5	3.7
Greateſt diameter of the chamber	—	6.6	4.5	4	3	2.7
Leaſt diameter of the chamber	—	6	3.6	3.4	2.4	1.4
Diameter of the muzzle ring	—	21	15.15	11.2	8	6.4
Breadth of the muzzle ring	—	1.1	.8	.6	.7	.5
Breadth of the aſtragals and fillets	—	1.25	1.0	.75	0	0
Diſtant from the muzzle ring	—	1.5	1.0	1.0	0	0
Diameter near the muzzle aſtragal	—	18.1	13.2	10	6.9	5.6
Diameter near the reinforce	—	18.1	13.2	10.0	6.9	5.6
Diameter of the reinforce	—	21	15.15	15.1	8	6.4
Breadth of the ogees	—	1.5	1.0	1.0	0	0
Diameter behind the breech aſtragal	—	18.1	13.2	9.8	6.9	5.9
Chamber contains powder	—	lb. 9:1:8	4:0:0	2:0:10	1:0:10	0:8:0
Weight of the mortar	—	C. 25:0:0	10:2:18	4:0:20	1:1:0	0:3:0
Weight of the ſhell when filled	—	C. 1:2:25	0:3:2	0:1:17	0:0:13	0:0:7
Shell contains powder	—	lb. 9:4:8	4:14:12	2:3:8	1:1:8	0:8:0

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N. B. The extremity of the bore is made round, and formed by an arc, whoſe radius is equal to that of the bore, and terminated by the lines which form the chamber: the bottom of the chamber is ſemicircular, the outſide of the metal is determined by a circular arc, deſcribed from the ſame center as the bottom of the chamber, and touching the lines drawn parallel to its ſides.

As all the neceſſary dimenſions are ſet down here accurately, the reader may eaſily conſtruct theſe mortars by the help of the plate, which ſhews their form; for which reaſon we ſhall inſiſt no farther upon them.

Dimenſions of ſea mortars in inches. Fig. 6, 7.

Diameter of the bore — —	13	10
Length of the mortar — —	63	56
From the muzzle to the reinforce	21	20
Length of the reinforce ——	18	12
Length of the bore — —	24	30
Length of the chamber ——	21	15
Its greateſt diameter — —	8.5	6.6
Its leaſt diameter — —	7	6
Breadth of the muzzle ring —	3	2.4
Of the muzzle, ogee, and fillet	1.9	0
From the muzzle to the aſtragal	0	.4
Of the aſtragals — —	0	1.6
Of the reinforce rings ——	1.9	0
Of the ogees next to them —	4.5	2.2
Of the chace ring — —	1.5	0
Of the chace ogee — —	2.2	0
Of the chamber aſtragal ——	0	1.6
Thickneſs of metal at the muzzle	4.7	2.8
At the muzzle ring — —	5.¾	6
Near the reinforce — —	4.7	3.3
At the reinforce — —	8	6
Behind the reinforce — —	9.5	6
Trunions length from end to end	45.4	36

Its

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Its greateſt diameter — —	12	0
Its leaſt diameter — —	10	8
Length of the part diminiſhed —	6	0
Chamber contains powder ℔	32	12 : 8
Weight of the mortar — C.	81 : 1 : 18	32 : 3 : 7

N. B. The thickneſs of metal at the muzzle, and near the reinforce, is taken from the lines produced, which determine the bore of the mortar; and behind the reinforce it is taken from the lines, which terminate the chamber. The round part or the breech of the mortar is circular, and deſcribed from the ſame centre as the bottom of the chamber in the 10 inch, and ſo as to come within 3.5 inches of the end of the mortar in the 13 inch; and in both ſo as to touch the outlines, which are drawn parallel to the ſides of the chamber.

The reader may eaſily perceive, that wherever ſtands an o in the two laſt tables, there is no ſuch dimenſion in that mortar; for there are mouldings in one which are not in the other.

Dimenſions of HOWITZES *by inches.* Fig. 8.

Diameter of the bore — —	10	8
From the muzzle to the reinforce	19.4	16
Length of the reinforce ——	11.9	10.7
Total length of the howitz —	50.4	37.4
Length of the bore — —	29.2	25.9
Length of the chamber —	16.8	9.9
Its greateſt diameter — —	6.5	4.6
Its leaſt diameter — —	5.6	4
Breadth of the muzzle ring —	1.7	1.25
From the muzzle ring to the aſtragal	4.3	4.6
Breadth of the aſtragal ——	1.3	.7
Of the ogee before the reinforce	2.	1.4
Of the ogee behind the reinforce	1.7	0

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Of the aſtragal — —	1.4	.7
Of the baſe ring — —	1.8	1.25
From the baſe ring to the aſtragal	2.2	0
Breadth of the aſtragal —	1.3	0
Thickneſs of metal at the muzzle	2.75	2.25
At the muzzle ring — —	5	3.4
Near the reinforce — —	3.4	2.6
At the reinforce — —	5.0	3.4
Behind the reinforce — —	4.4	2.5
Diameter of the baſe ring —	20	14.7
Diameter at the vent aſtragal —	17.5	12.5
Diameter of the caſcable —	8.25	7.6
Diameter of the button —	7	3
Diameter of the neck —	5	3.5
Breadth of the ogee and fillets	1	.9
Of the ſecond ogee and fillets	1.6	.9
Diameter of the firſt fillet —	11.13	9.5
Diameter of the ſecond —	7.64	4.5
Length and diameter of the trunion	6.	4.4
From the fore reinforce to the trunion	2.	1.2
Chamber contains powder ℔	18	4
Weight of the howitz — C.	31 : 2 : 26	12 : 1 : 11

Remarks on the conſtruction of MORTARS.

Of all the parts of Artillery, the conſtruction of mortars is the moſt variable and uncertain; almoſt every artilleriſt has ſome favourite notion or other concerning their figure. Mr. *Belidor* mentions, in his *Bombardier François*, four different chambers; namely, the cylindric, the ſpheric, the conic, and the bottled; of theſe he ſays the cylindric is the worſt, and the conic the beſt; for, ſays he, the vent being at the end of the cylindric chamber, prevents the powder from taking fire ſo quick as in the conical one; he alledges likewiſe another reaſon againſt the uſe of theſe chambers, which is, that they are ſeldom caſt ſo as their axis correſponds with

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with that of the bore, whereby the direction of the ſhell becomes variable and uncertain.

But ſince there is no neceſſity for placing the vent at the end of the chamber, as he ſuppoſes, all his arguments on that account can only be againſt the preſent practice, and by no means proves their badneſs; and had he conſidered the exploſion of powder as an elaſtic fluid, as he ought, he would have eaſily perceived that the direction of the chamber, with regard to that of the ſhells, is of no conſequence, ſince the action of fired powder is every-where perpendicular to the ſurface it acts upon. Beſides, according to the experiments I made, which are mentioned in the preface, the force of powder, when fired at the end, is greater than when fired in the middle. I dare not however infer, that the ſame thing will happen in larger mortars, becauſe I have found by experience, that we ought to depend upon nothing but what has been found to anſwer in pieces of the ſame caliber; and therefore all the different ſizes of mortars ſhould be tried and examined, to determine where the vent is to be placed in the moſt advantageous manner.

We have proved in the fifth Theorem, and the examples that follow, that the action of fired powder diminiſhes in proportion as the ſurface preſſed enlarges; the ſame thing we have likewiſe found by experiments, and therefore the conic chambers are the very worſt of all.

The late General *Borgard* made his chambers likewiſe conical, terminating in a circular form at the bottom, as has been ſhewn in the foregoing tables of the dimenſions; and ſo as the ſides of the chamber produced meet the extremities of the diameter at the mouth; imagining, I ſuppoſe, that the powder acts in right lines parallel to the ſides of the chamber. Though he was one of the braveſt officers of his time, and ſerved about ſeventy years, yet his qualifications as an inventor were but very moderate.

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As to the advantage of concave chambers of any kind, it consists in this, that their entrance may be made narrower than those of any other form, and that this is a real advantage, we have proved both by theory and practice: yet when the entrance is so small as not to admit of a man's hand, they are not easily cleaned; and if any sparks of fire should remain, cannot be so well extinguished; for which reason I would make them of this form only in sea mortars, because they are loaded with large quantities of powder, and in the land ones cylindric: since these latter need be charged with but little powder.

As to the vulgar notion, that mortars with concave chambers, when fired, shake their beds with great violence, and make the direction of the shell very uncertain, it is grounded upon ignorance, and deserves no notice.

The length of mortars is no more ascertained than the rest of the dimensions: the *French* make the length of the bore a diameter and an half of the shell; on the contrary, we make that of our land mortars two of these diameters, and three in the ten inch sea mortar, which causes a great difference in the weights; for our thirteen inch land mortars weigh C. 25 : 0 : 0, whereas the *French* weigh only C. 13 : 0 : 0.

It is a query, whether this difference produces any material advantage in the ranges; if not, it would be unnecessary to make them so long as we do, since this increase makes them so much the heavier. For the same thing (*viz.* that those guns which carry farthest are not the best) is also true in mortars; since if they carry their shells about 12 or 1500 yards with a moderate charge, it is in my opinion sufficient in respect to land mortars; because when they carry farther, the hitting an object becomes so extremely uncertain, as to render that advantage useless; therefore all means should be tried to make them as light as conveniently can be.

The

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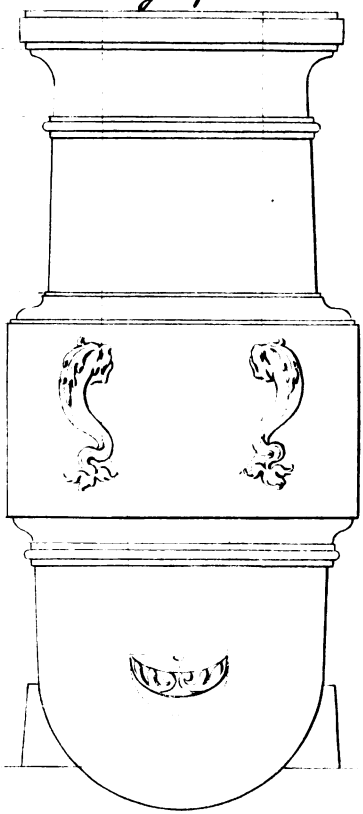
Fig 7



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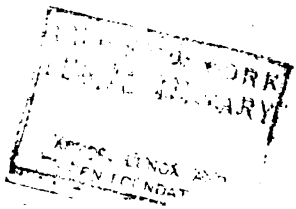

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The thickneſs of metal in the different parts of a mortar, is as undetermined as the reſt; for not any two ſorts are equally ſtrong; ſome are as much too weak as others the reverſe, and thoſe who have the direction of theſe things are ſo ſlightly acquainted with the common principles of geometry, that when a mortar of any ſize is made with proper dimenſions, and has been found in practice to anſwer perfectly well, they cannot make another either leſs or larger, that ſhall ſtill retain the properties of the former.

The reaſon is, that commonly none but workmen are employed on them, whoſe knowledge conſiſts only in imitation and gueſs. For though a workman may be very capable to execute the work, or to ſee it done, yet it can hardly be ſuppoſed that he is able to determine the proper dimenſions of the ſeveral parts.

The parts of mortars are formed in imitation of thoſe of guns; for which reaſon they make them with a reinforce. This only overloads the mortar with a heap of uſeleſs metal, and that in a place where the leaſt ſtrength is required; yet, as if this unneceſſary metal was not ſufficient, they add a great projection at the mouth, which ſerves to no other purpoſe than to make the mortar top-heavy. The mouldings are likewiſe jumbled together, without any taſte or method, though they are taken from architecture.

As there has not the leaſt hint hitherto been given, with regard to a general rule to conſtruct all ſizes of mortars by, without which, the artilleriſt cannot poſſibly underſtand what he is about, nor can he judge whether he is right or wrong, whenever he attempts to conſtruct others of a different ſize from thoſe in uſe at preſent, he muſt remain in ignorance, let him take ever ſo much pains, we ſhall give the following rules.

General

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General dimenſions for land mortars.

Plate III. Fig. 9.

Diameter of the bore	30	30	30
Diameter of the chamber	10	10	10
Length of the bore	54	45	40
Length of the chamber	22	21	20
From the end of the chamber to the end of the mortar	16	15	14
Total length of the mortar	92	81	74
From the mouth *a* to the reinforce *b*	30	26	22
Length of the reinforce *b c*	18	14	14
Breadth of the muzzle ring and fillets	3. 5	3	3
Breadth of the ogee next to it	3	2	2
From the ogee to the muzzle aſtragal	5	4	3
Breadth of the aſtragal and fillets	2. 5	2	2
Breadth of the ogee before the reinforce	3	2	2
Breadth of the two ogees and fillets behind the reinforce	6	5	4
Thickneſs of metal at the muzzle	5	4. 5	4
Thickneſs of metal near the reinforce	6	5	4. 5
Thickneſs of metal at the reinforce	7	5. 5	5
Thickneſs of metal at the chamber	12	12	12
Thickneſs of metal at the muzzle ring	6. 5	5. 5	5
Diameter of the trunions	14	13	12
Length of the trunions from the mortar	15	14	13
Chamber contains powder	*d* 421	*d* 442	*d* 466
Weight of the mortar	*5d* 6	*2d* 3	*3d* 5

N. B.

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N. B. The chamber is cylindric, and the bottom a ſemi-ſphere; the round part of the mortar is deſcribed from the ſame center as the bottom of the chamber. The letter *d* in the content of the chamber and that of the weight of metal, expreſſes the cube of the diameter of the bore in inches; that is, $d = 2197$ in a thirteen inch mortar, and $d = 1000$ in a ten inch.

The reader may ſee that the diameter of the bore is to be divided into 30 equal parts, for a ſcale to ſet off all the reſt of the dimenſions. The ſame ſcale ſerves to conſtruct their beds, which renders the whole eaſy and uniform, a neceſſary conſequence of well ſettled principles.

Remarks on theſe dimenſions.

We have endeavoured to diſpoſe the metal in ſuch a manner, as to make the ſtrength of the parts nearly in proportion to the forces which act upon them: at the chamber it is ſufficient, though leſs than in moſt mortars now in uſe; for the thickneſs of metal there is greater than its diameter, which is more than ever has been allowed in any braſs gun whatever; it is true that the effort alſo is greater, but then an allowance has been made accordingly: we made a reinforce, merely to comply in ſome manner with the common practice, though the mortar ſhould be conical from the chamber to the mouth, according to the action of powder, as proved before; however, the difference between the reinforce and chace is no more than juſt ſufficient to admit of an ogee, whereby the mortar looks more graceful to the eye; at the mouth the projection is no greater than is neceſſary for the mouldings, more would be ſuperfluous, and make the mortar top-heavy; beſides, as we ſuppoſe it capable of being either raiſed or depreſſed, and not fixed to its bed, as hitherto the cuſtom, that operation would thereby become more difficult. As

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to the vent, we do not pretend to determine its true place, though we have always found the nearer it was to the bottom the farther the ſhell went; but as theſe experiments were made with a three inch mortar only, no juſt concluſion can be drawn from thence with regard to larger.

The cylindric figure of the chamber, is, in my opinion, the beſt for theſe kind of mortars; for though we have ſhewn that the concave figure, or thoſe whoſe entrance was the leaſt, will throw the ſhell fartheſt of any with the ſame charge; yet in this caſe, where but little powder is required, their entrance would become too narrow and inconvenient to clean; whereas when they are cylindric, the difference between the advantage of the one and the other will be but little, and not attended with any inconveniencies.

Colonel *Deſaguliers* and myſelf made ſeveral experiments with different chambers, which contained the ſame quantity of powder, and we found that the cylindric threw the ſhell always farther than any other whoſe entrance was larger, and more eſpecially when they were not quite filled. We made likewiſe ſome other experiments, which were, by putting as much powder as would fill half the chamber into a cartridge made of common writing paper, and when it was put into the chamber, ſo as to be cloſe to the ſhell, leaving a vacancy at the bottom, it threw the ſhell near twice as far as when the cartridge touched the bottom, and the vacancy was left between the ſhell and the powder; we repeated this experiment ſeveral times, and found always the ſame effect. Another remarkable thing happened; I put a piece of common writing paper upon the powder, the chamber being but partly filled, and the ſhell went much farther than with the ſame charge when there was no paper. Laſtly, we compared two chambers of the ſame content, the one cylindrical, and the other conical; they had both the ſame height, and the diameter of the bottom of the conical one was but half the diameter of

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the entrance, and when these chambers were not quite full, the cylindric one threw the shell much farther than the other, and this happened as often as the experiment was repeated. Whoever considers these experiments with some attention will find, that we know very little of the effects of gunpowder as yet, and that we ought to depend upon nothing but what has been tried.

That our chambers hold a sufficient quantity of powder, for any occasion whatever, has been proved by experiments; for I fired a three inch mortar, with an ounce and a quarter of powder, at an angle of elevation of 45 degrees, and the shell went 1200 yards; and since our mortars are similar to that tried, the powder will give the shell the same velocity; but because the resistance of the air is in this case inversely as the shells diameters, the three inch shell will meet above four times the resistance of a thirteen inch shell; from whence, and some other experiments made upon *Woolwich Common*, with the present thirteen inch mortar, I conclude, that the shells in our mortar will range about a mile, which is more than is wanted; for when the ranges are greater, they are so uncertain, and it is so difficult to judge how far the shell falls short, or exceeds the distance of the object, that it serves to no other purpose than to throw away the powder and shell, without being able to do any execution.

The first of these mortars is of the same length with our land mortars; the second with the *French*; but the third is shorter than either. The reader may easily see, that these dimensions are general for any size of mortars whatever, as all constructions ought to be, whereby they become all alike; and consequently one of them being found strong enough by practice or experience, all the rest will be so too; which can never be the case in particular constructions, as hitherto has been the case in all countries so far as I know.

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To find the weight of metal.

The ſquare of the mean diameter 41 of the muzzle part, multiplied by 30, gives —	50430
The ſquare of the diameter 44 of the reinforce, multiplied by 18, gives —	34848
The ſquare of 34, the chamber part, multiplied by 34 $\frac{1}{3}$, gives — —	39689
Four times the trunion 2940, for the trunions and mouldings — — —	11760
Sum total in cubic parts of the diameter of the bore — — —	136727
The content of the bore in like parts is —	44100
The content of the chamber is —	2033
The two laſt ſums ſubtracted from the content of the mortar, leaves — —	90594
This reduced in the ratio of 452, to 355, of the ſquare of the diameter to the circle, gives — — —	71152
Then as 192 cubic inches weigh 61 pounds of metal, we get — —	22605

But as the diameter *d* is divided into 30 equal parts; if we ſay, as the cube of 30 is to the cube *d*, ſo is 22605 to the weight of the mortar of the firſt ſort, it will be found to be $\frac{5}{6}\,d$ nearly. In the ſame manner are found the weights of metal of the other two mortars.

To find the contents of the chambers.

The ſquare of 10 multiplied by the length, reduced 20 $\frac{1}{3}$, gives 2033 in the firſt mortar; but as the diameter is divided into 30 equal parts, if we ſay as the cube of 30 is to the cube *d*, ſo is 2033 to $\frac{2033}{27000}\,d$, we get

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get the cubic parts of the diameter. Now, becauſe the diameter of a cylinder, which holds one pound of powder, is 3.165, according to Sir *Jonas Moor*, if we divide the laſt number by 31.7, the cube of that diameter, we ſhall have $\frac{2033}{8559^{00}}\,d$, for the content of the chamber; which being reduced, gives $\frac{d}{421}$ or $\frac{d}{531}$ nearly. In the ſame manner are found the contents of the chambers of the other mortars.

In order to compare theſe mortars with thoſe uſed at preſent, we ſhall inſert their weights and charges in the following tables.

Weight of the new mortars.

Diam.	13	10	8	6
Firſt	16 : 1 : 10	7 : 1 : 21	3 : 3 : 6	1 : 2 : 11
Second	13 : 0 : 0	5 : 3 : 22	3 : 0 : 0	1 : 1 : 0
Third	11 : 3 : 0	5 : 1 : 12	2 : 2 : 27	1 : 0 : 15

Weight of the powder.

Diam.	13	10	8	6
Firſt	5 : 3	2 : 6	1 : 3	0 : 8. 2
Second	4 : 15	2 : 4	1 : 2	0 : 7. 8
Third	4 : 11	2 : 2	1 : 1	0 : 7. 4

Weight

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Weight of the preſent mortars.

Diam.	13	10	8	5.8	4.6
Wt.	25:0:0	10:2:18	4:0:10	1:1:0	0:3:0
Cham.	9:1:8	4:0:0	2:0:10	1:0:0	0:8:0

Hence if we compare the weights of our mortars with thoſe of the preſent ones, we ſhall find the difference between the 13 inch to be, 8 : 2 : 18; between the 10 inch, 3 : 0 : 15, and between the 8 inch, 0 : 1 : 4. Now as the difference between the weights of the 13 inch mortars, is much greater than between any others, it is evident they are much heavier in proportion than they ought to be, in reſpect of the ſmall ones; it appears therefore, that no true proportion has been obſerved in their conſtruction.

Though our mortars are ſo much lighter than the preſent ones, yet I may affirm, they are equally ſtrong, becauſe they are as thick at the chamber as they need be; and at the muzzle, or where the leaſt thickneſs is, ours are ſtronger; for the 8 inch mortar is but an inch in that place, whereas ours is 1 inch and a third; the 10 inch, is 1.6 inches thick, ours 1 $\frac{2}{3}$; and as to the reinforce, it is loaded with more metal than it need be, ſince the force of powder is very little more there than at the muzzle. But the difference between the weights ariſes chiefly from the chambers, which are both wider and longer in the preſent mortars than in ours, and therefore they require more metal.

General Dimenſions of howitzes. Fig. 11.

Diameter of the bore, —— ——	30	30	30
Length of the bore, —— ——	90	90	97.5
Diameter of the chamber, ——	15	15	15

Length

Length of the chamber, — —	33	33	33
From the muzzle a, to the reinforce b, — —	50	50	54.5
Length of the reinforce b c, —	34	34	37
From the reinforce c, to the end of the howitz, — — —	50	50	50
Total length of the howitz, —	134	134	141.5
Thickneſs of the metal at the muzzle, — —	8	7	8
Thickneſs near the reinforce, —	9	8	9
Thickneſs at the reinforce, —	10	9	10
Thickneſs at the chamber, —	16	15	16
Breadth of the muzzle and baſe ring, fillets included, — —	5	5	5
Breadth of the ogees, that behind the reinforce excepted, —	3.5	3.5	3.5
Diſtance between the muzzle and breech, ogees and aſtragals, —	6	6	7
Breadth of the aſtragals and fillets,	3	3	3
Breadth of the ogee behind the reinforce, — —	6	6	6
The muzzle and baſe ring project the metal by — —	1.5	1.5	1.5
Length of the trunions — —	18	18	18
Diameter of the trunions — —	15	15	15
Diſtance of the trunions from the fore end of the reinforce, —	5	5	5
	d	d	d
The chamber contains powder, —	116	116	116
Weight of the howitz, —	2.25d	1.97d	2.4d

The caſcable is 24 parts long, the radius of the button 8, the ogee and fillet included 4.

The reader may obſerve, that for want of room in the plate, the button could not be marked, which he may eaſily ſupply from the given dimenſion in the ſame manner as in guns.

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The dimenſions of the firſt howitz are nearly the ſame as thoſe of the preſent, the chamber part excepted; the reinforce is not ſo ſtrong as it is commonly made, without any ground or reaſon, becauſe the force of exploſion acts but very little more there than at the muzzle. The dimenſions of the ſecond are leſs, and yet I am perſuaded ſufficient; for a 6 inch howitz is an inch and .4 thick near the muzzle, whereas the preſent 8 inch mortar is barely an inch in that place; for which reaſon I would prefer the ſecond ſort before the firſt, becauſe there can be no reaſon aſſigned to load them with more metal than is neceſſary.

The third ſort is a quarter of the bore's diameter longer than the other two, and the reſt of the dimenſions the ſame as the firſt; hence the artilleriſt is left to his choice to uſe which he likes beſt.

Weight of the howitzes and powder.

Bore, ——		13	10	8	6
Weight	1ſt,	44: 0:13	20:0: 9	10:1: 0	4: 1: 5
	2d,	38: 2: 8	17:2: 3	9:0: 0	3: 2:24
	3d,	47: 0: 7	21:1:14	10:3:13	4: 2: 6
Powder,		18:15: 0	8:9:14	4:6: 9	1:13:12

Weight of the preſent howitzes and powder.

Bore, —	10	8	5.8
Weight,	31 : 3 : 26	12 : 1 : 6	4 : 0 : 18
Powder,	18 : 0 : 0	4 : 0 : 0	1 : 0 : 0

From

From these tables of the weights of howitzes, we see that the present 10 inch weighs about one third more than it should do in respect to the 8 inch, for the weights should be in proportion to the cubes of the diameters. Now the cube 512, of 8, is to the cube 1000, of 10, as the weight 12 : 1 : 6, of the 8 inch, is to the weight 24 : 0 : 3, which should be the weight of the 10 inch. Whence it evidently appears, that no better proportions have been followed in constructing howitzes than mortars.

This superfluous weight of the 10 inch howitz has occasioned its disuse, at least these 25 years; whereas by observing a due proportion, and such as our second sort, not only a 10 inch but even a 13 inch might have been used, if it had been thought proper. It may be observed again, that though ours are so much lighter than the others, they are full as strong, because the metal is better disposed over all the parts, and there is not that useless lump at the muzzle, reinforce, and trunions, as in those made at present.

It is to be wondered that no greater use has hitherto been made of howitzes, since the shells may do execution likewise as shots, and besides grapes of shots, or shells, might be fired out of them to more advantage than out of guns, especially in a siege where the distance is but small; and in the field, if they were placed in the flanks, or between the battalions; the terror they would cause, especially amongst the horse, by rolling amongst the ranks with the fuse burning, and the expectation of their bursting every moment, would disorder the bravest men, by means whereof they might easily be broke, and the day thereby won.

In a siege where the works are not lined with walls, or when the walls are once battered down by cannon, there can be no speedier way to complete the breach than by firing shells into them; for they will lodge in the earth, and when they burst will produce the same effect as mines. This practice has been recommended by

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St. Remy, and the *French* followed it in the ſiege of *Bergen-op-zoom*, where they chiefly uſed mortars, mounted upon field carriages for that purpoſe; beſides, when you are pretty near the enemy's works, grapes made of ſhells will do wonderful execution, as I have been aſſured by ſome artillery officers, who have tried it, and found that all the fuſes took fire.

As howitzes are eaſier carried from one place to another than mortars, which require alſo a good deal of time to prepare the ground, to lay the beds, and mount them, the uſe of the former would be more convenient than the latter in all caſes, except in throwing ſhells upon powder magazines. It may be obſerved, that the wheels and axletree of the preſent 10 and 8 inch howitz carriages, are of the ſame ſtrength as thoſe of a 24 and 18 pounder's carriages, without any judgment or reaſon. For ſince the wheels of an 18 pounder's carriage ſupport a weight of 48 : 0 : 0, which is juſt four times the weight of the 8 inch howitz, there is not the leaſt proportion obſerved between the weight and the ſtrength to ſupport it; it is true, that an 8 inch ſhell is heavier than an 18 pound ball, but when it is conſidered that the force of the ſhell affects the carriage in its recoil only, and not at all the wheels; this can be no reaſon for making them ſo ſtrong as has hitherto been the cuſtom.

Of ſea mortars.

As theſe mortars are generally fired at a much greater diſtance than ever is required by land, they are made ſomething longer and much heavier than the land. Their proper dimenſions can only be determined from their charges of powder. The chamber of the preſent 13 inch holds 32 pounds of powder, though the late General *Borgard* told me, he never made uſe of more than 12 pounds, and as he had more experience in that ſervice than perhaps any other, we may depend on what he

be ſaid; beſides, ſome very expert officers employed in the late war aſſured me, they never exceeded the charge of 15 pounds. Now, as this chamber is never half filled, the powder won't act ſo forcibly as if there was no vacant ſpace between the charge and the ſhell; it is therefore plain, that a charge of 12 or 15 pounds of powder at moſt will be ſufficient; beſides, this chamber being conical, and its greateſt baſe two thirds of the diameter of the bore, leſſens the force of powder conſiderably, and more ſo when not filled, as Colonel *Deſaguliers* and myſelf found by ſeveral experiments made with ſuch a chamber, and compared with a cylindric one of the ſame content. This being an undoubted fact, the following dimenſions will, I may venture to affirm, be ſufficient in all reſpects.

General dimenſions of ſea mortars. Fig. 10.

Diameter of the bore divided into — —	30	30
Length of the bore, — — —	75	75
Diameter of the chamber, — —	15	15
Length of the chamber, — —	33	33
From the end of the chamber to the end of the mortar, — — —	20	20
Total length of the mortar, — —	128	128
From the muzzle a, to the the reinforce b,	43	43
Length of the reinforce b c, — — —	23	28
Thickneſs of the metal at the muzzle, mouldings excepted, — — —	8	7
Thickneſs of metal { near the reinforce, —	9	8
Thickneſs of metal { at the reinforce, —	10	9
Thickneſs of metal { at the chamber, —	16	16
Breadth of the { muzzle ring and fillets, —	4	4
Breadth of the { ogee next to it, and of that before the reinforce, —	3	3
Diſtance from the ogee to the muzzle aſtragal, — — —	6	6

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Breadth of the astragal and fillets,	3	3
Breadth of the ogee behind the reinforce,	4	4
The muzzle ring projects the metal, by	1. 5	1. 5
Diameter of the trunions,	18	18
Length of the trunions from the mortar,	20	20
	d	*d*
The content of the chamber,	126	126
Weight of the metal,	2. 1*d*	1. 8*d*

The arcs which determine the round part of the mortar are described from the same center which determines the bottom of the chamber: the weight of metal, and that of the powder which the chamber contains, have been found in the same manner as in the guns, allowing four times the value of one trunion for the trunions and mouldings.

Weight of sea mortars and powder.

Diameter of the bore,	13	10
Weight of present sea mortars,	81 : 1 : 18	32 : 3 : 7
Weight of the first new mortar,	41 : 0 : 19	18 : 2 : 19
Weight of the second,	35 : 1 : 2	16 : 0 : 7
Powd. cont. in present mortars,	32 : 0 : 0	12 : 8 : 0
Powd. cont. in new mortars,	17 : 7 : 0	8 : 0 : 0

The enormous weight of the present 13 inch mortar proceeds from the antient notion, that those pieces which throw a shell fartheſt are the beſt; for which reaſon the artiſt imagined, that the heavier they were, the farther they would carry. But by the account of all those artillery officers whom I have converſed with, and who have been employed in that ſervice, the ſhip or bomb-ketch is not able to bear the ſhock of those mortars, when loaded with their chambers full of powder; and conſequently it is ridiculous to make them ſo heavy.

The

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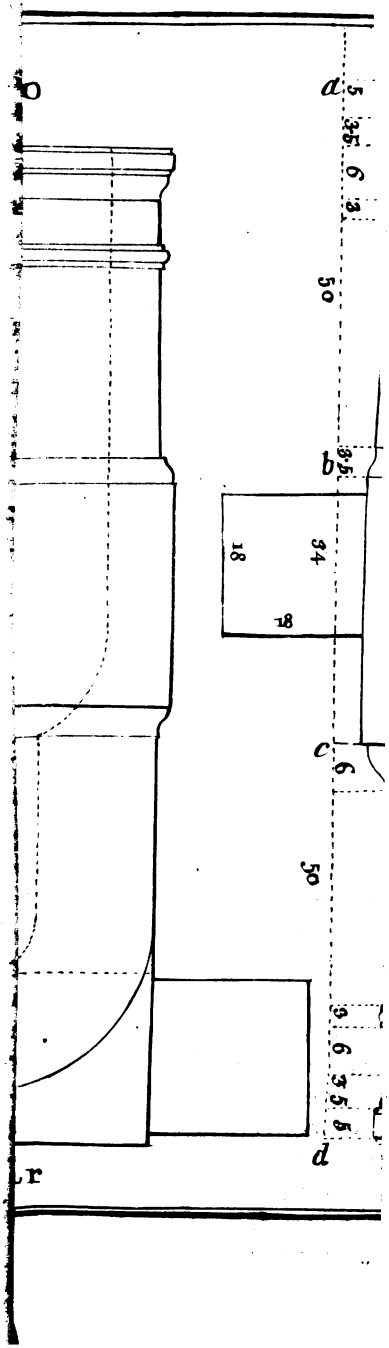

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The firſt of the new mortars is as ſtrong at the muzzle as the 10 inch preſent one, and conſequently ſtrong enough upon all occaſions; and I may venture to affirm, that the ſecond ſort is ſo too; ſince it is above twice as ſtrong as the land. With regard to the ſize of our chambers, we have ſhewn before, that they never uſe above 15 pounds of powder in bombarding; we have likewiſe proved in the theory of powder, as well as by ſeveral experiments, the great advantage a cylindric chamber has over the conic when the greateſt baſe is uppermoſt, ſo that there cannot remain the leaſt doubt but that our chambers are full as large as they need be on any occaſion.

It may appear ſtrange to ſome of my readers, that mortars ſo much lighter than the preſent ſhould be near equally ſtrong. I account for it in this manner, their chambers are near twice as long as ours, and as the thickneſs is very great in that place, there muſt needs be a great deal more metal there than is neceſſary; the ſame thing may be ſaid with reſpect to the reinforce part, which without any reaſon is made about twice as ſtrong as the muzzle part; though the force of exploſion is nearly the ſame in both places. This was never conſidered in the conſtructions of old mortars.

In the bombarding of *Havre de Grace*, the mortars were fired quick and with a full charge, by which they were ſpoiled and rendered uſeleſs in a ſhort time; for the vents grew ſo large, and the metal melted in the chambers, that it would have been dangerous to fire them any more, and ſo were rendered entirely uſeleſs.

It has been obſerved both in guns and mortars, that the great thickneſs of metal, inſtead of being an advantage, renders them ſooner uſeleſs. For at the battle at *Lafeldt* ſeveral 6 pounders, that weighed 1900, were ſpoiled, and the light, which weighed but 4 : 3 : 0, received no damage; and our ſea mortars generally fail when much fired with great charges; whereas the land, which do not weigh one third of the others, ſcarcely

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ſcarcely ever fail: the reaſon of this is imagined to be, that thin metal heats not imperceptibly ſooner than thicker, and cools much ſooner; and when thick metal is once much heated requires a longer time in loading, and conſequently accumulates the heat to ſuch a degree as to make it incapable to reſiſt the ſhock of the fire. This is confirmed by experience.

Plate IV. Fig. 12.

The following mortar with a concave chamber is, I think, preferable to the two former; the baſe a b, or c d, is ten parts; the diſtance between the lines a b, and c d, is 26 parts; and its greateſt tranſverſe diameter 20; the thickneſs of metal at the chamber is 16 parts, as before; the outſide form is ſimilar to that of the chamber, and all the other dimenſions are the ſame as thoſe of the firſt of the two preceding mortars. This mortar will weigh nearly as much, and its chamber contain the ſame quantity of powder as the firſt; but as the entrance of it is to that of the former, as 4 to 9, the powder will act with a greater force; for which reaſon it is preferable.

As the entrance is wide enough to introduce the hand, and clean it without any inconveniency, it may be loaded with as much eaſe as any other; whereby we avoid the objection made by ſome againſt theſe kinds of chambers.

As to the placing the vent both in guns and mortars in the beſt manner, I muſt confeſs it is beyond my knowledge; and it appears to me, that nothing but experiments can determine it; for thoſe I made with two ſmall mortars appear ſo contradictory to theory, and the notion we have in reſpect to the exploſion of powder, that I am more uncertain than ever; and it is very probable they will vary more in thoſe of larger calibers, for which reaſon we leave it undetermined. I ſuppoſe it, in all the preceding draughts, pretty near the end of the chamber;

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chamber; becauſe the few experiments I made ſhewed that to be the beſt place in ſmall mortars.

SHELLS. Plate IV. Fig. 14.

As the dimenſions of ſhells are undetermined, and no proportion obſerved therein, nor is it known how much the thickneſs of the bottom ought to exceed that at the fuſe hole, ſo as they may burſt in the greateſt number of pieces, we have in the following dimenſions obſerved the proportions of the preſent 13 inch ones; ſo that if they are right, we are certain that ours will be ſo too; but if it ſhould ſo happen, that the ſhell of any other caliber is found to have a better proportion than that we have made uſe of, the general dimenſions may eaſily be made in the ſame proportion, by ſaying, the diameter of the ſhell is to 30, as any part expreſſed in inches, is to the ſame part, expreſſed in parts of the diameter divided into 30 equal parts.

Diameter	of the bore,	30
	c d of the ſhell,	29.5
	of the hollow ſphere,	21
Thickneſs	of metal at the fuſe hole,	3.5
	at the bottom or oppoſite part	5
Diameter a b of the fuſe hole,		4
		d
The weight of the ſhell unloaded,		11.7
Weight of the powder the ſhell contains		236.5

The fuſe hole is conical, and when produced, terminates at the extremity d of the diameter c d, which paſſes through the center.

There are two handles of hammered iron fixed in the mould when they are caſt, which faſten to the ſhell, and ſerve to lay hold on when the mortar is to be loaded thereby, as likewiſe to carry them from one place to another.

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other. In *France* theſe handles are caſt iron; but this renders them clumſier, and liable to break ſooner than the others. The letter *d* ſtands here for the cube of the diameter of the bore, as well as in the conſtruction of mortars.

Two reaſons are given for making ſhells thicker at the bottom than at the fuſe hole; one is, that they are thereby better enabled to reſiſt the ſhock or impreſſion of the powder that diſcharges them; the ſecond, that the ſhell always falling with the heavieſt part undermoſt, the fuſe will of courſe be uppermoſt, and therefore will not be extinguiſhed by its fall. Both theſe reaſons are, in my opinion, of no conſequence; for if the ſhells were every-where equally thick, and of the ſame weight as thoſe above-mentioned, the blaſt of powder lodged in the chamber would hardly be able to break them; and as to the fuſe falling uppermoſt or not, that is of no detriment, ſince the compoſition of fuſes is ſuch, that nothing but an abſolute ſtoppage from the air is able to choak them; for they burn in water as well as any other element; for which reaſon I would make them every where equally thick, becauſe they would then burſt into a greater number of pieces. But to be certain, it would be eaſy to make the experiment.

The quantity of powder they ought to be filled with, ſo as to burſt into moſt pieces, is not known; but moſt artilleriſts agree that they ſhould not be quite full; and Colonel *Deſaguliers*, after having made ſeveral experiments, imagines, that two thirds of the weight which would fill them is the quantity they ſhould be loaded with.

Weights of the preſent ſhells and powder.

Bore,	13	10	8	5.8	4.6
Wt.	1 : 2 : 15	0 : 2 : 25	0 : 1 : 15	0 : 0 : 12	0 : 0 : 7
Powd.	9 : 4 : 8	4 : 14 : 12	2 : 3 : 8	1 : 1 : 8	0 : 8 : 0

Weight

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Weights of the new ſhells and powder.

Bore,	13	10	8	5.8	4.6
Wt.	1 : 2 : 15	0 : 2 : 27	0 : 1 : 14	0 : 0 : 16	0 : 0 : 8
Powd.	9 : 4 : 8	4 : 3 : 10	2 : 2 : 10	0 : 13 : 3	0 : 6 : 9

It is to be obſerved, that the windage of the preſent ſhells is a quarter of an inch, let them be great or ſmall, which is contrary to all reaſon; whereas we allow $\frac{1}{60}$ part of the bore's diameter, which is ſomething leſs in a 13 inch one, and decreaſes in proportion to the ſhell's diameter; whereby our ſmall ſhells become ſomething heavier than the preſent.

There is another kind of mortar which ſerves to fling ſtones into an enemy's works, when near at hand; ſuch as from the town into the trenches in the covert way, or upon the glacis, and from theſe trenches into the town, or ravelins. As we have none of that ſort here, I ſhall give ſuch dimenſions as agree nearly with thoſe mentioned in *St. Remy*, whoſe diameter is 15 inches.

Dimenſions of ſtone mortars. Fig. 13.

Diameter of the bore,	30
Length of the bore,	37
Length of the chamber,	16
Its greateſt diameter	8
Its leaſt diameter,	6
Diameter of the cylindric part to hold a wooden tapeon,	14
Depth or axis of that cylinder,	3
From the muzzle to the reinforce	20.5
Length of the reinforce	8

Thickneſs

Thickneſs of the metal at the	muzzle, — —	3·5
	reinforce, — —	4·5
	chamber belt, —	9
	entrance of the chamber, —	6
The chamber enters into the trunions, by —		2
Diameter of the trunions, — — —		40
Length from end to end of the trunions, —		40
Breadth of the	muzzle ring and fillets, —	3
	chamber belt, — — —	2
	ogee next to this belt, —	3
		d
Content of the chamber, —		1102
Weight of the metal contained in this mortar,		3·1

The bore is terminated by two quadrants of a circle, terminated by the reinforce and lines drawn from the ends of the cylinder made to lodge the tapeon parallel to the axis of the mortar; and the round part on the outſide are arcs deſcribed from centers, taken in the line which terminates the reinforce, and ſo as to meet the extremities of the belt. The bottom of the conic chamber is terminated by an arc of 60 degrees, and the round part of the outſide is a ſemicircle.

Thus a 15 inch ſtone mortar weighs 10 : 3 : 4, and the chamber contains 3 pounds of powder; this agrees very nearly with the *French* mortar of the ſame ſize, which weigh 1000 pounds. When it is conſidered that we made the chamber part ſtronger than theirs, we conceive that this mortar may likewiſe ſerve to throw baſkets full of hand-grenades, which will be much more dangerous to an enemy than ſtones.

The reader may eaſily perceive, that the conic chamber is very proper here in this caſe, as a great force is not ſo much required as the extent of that force againſt the tapeon, for fear it might break it in the middle.

The

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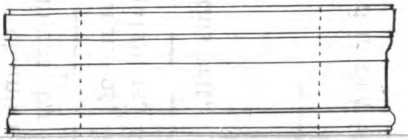
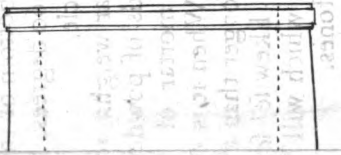
IV Sea Mortar

Witha Concave Chamber.



Stone Mortar



P. 156
92

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The form of the bore at the bottom being different from that in other mortars, is likewiſe adapted here to the bodies to be thrown out of it; baſkets are made to fit the bottom of the bore, which, when filled, are let into the mortar by means of two handles, in order to load it quicker. The ſtones generally made uſe of upon this occaſion are pebbles the bigneſs of a man's fiſt, and as round as can be found. But as we ſaid before, hand-grenades or ſmall ſhells made for that purpoſe, of about two or two and a half inches diameter, will anſwer the purpoſe much better than ſtones. This has been practiſed at *Bergen-op-zoom* with a common mortar, and ſucceeded to the ſatisfaction of the artillery officers who tried the experiment.

Having thus given general conſtructions for mortars uſed on all different occaſions either by ſea or land, it remains to ſhew in what the uſe of howitzes differs from that of common mortars; as they are carried upon gun travelling carriages, they are eaſily tranſported in the field from one place to another, and are more readily fired than the others; they have likewiſe another advantage, which is, that they may be laid to any elevation, whereas the common mortars are fixed upon their beds at an angle of 45 degrees, whereby they are not ſo uſeful in a ſiege: for the ſhells thrown into the works, either from the trenches into the fortification, or from the fortification into the trenches, ſhould always be directed in a leſs elevation than 45; and when they are to be thrown upon powder magazines, or any other building, with an intention to deſtroy it, the elevation ſhould be greater, in order that they may fall with more force.

All theſe conſiderations are ſeeming advantages in favour of the howitzes; but if we conſider that a 10 inch howitz weighs conſiderably more than a 13 inch mortar, and an 8 inch one more than a 10 inch mortar, it is eaſily perceived that the uſe of howitzes is not ſo ſuperior to that of the common mortars as is imagined by moſt artilleriſts. As to the different degrees of elevations in which

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which they may be directed, it is a property that mortars ought to have as well as they. For there is not the leaſt occaſion to fix them on their beds ſo as not to be moved, ſince no nation but this does it; nor to laſh them on their beds with ſo much cordage, as if their weight was not ſufficient to keep them in their ſituation. The reaſon given for this practice is, that if they were not laſhed to their beds they would kick up before, and fall backwards, which is trifling, and inconſiſtent with the rules of mechanics; beſides the *French* mortars, which are much lighter than ours, and are not tied, never overſet; and as no nation makes more uſe of them than they do, it is very improbable they ſhould neglect a thing of that kind if there was any neceſſity for it.

As to the advantage of carrying howitzes upon travelling carriages, it is as inſignificant as the reſt, ſince no reaſon can be given why mortars may not be carried in the ſame manner. That this may be done, appears from the practice of the *French* during the laſt war. But what will not people do to ſupport an old cuſtom let it be ever ſo abſurd?

PART IV.

Conſtruction of ſhip and travelling carriages.

THERE are three different ſorts of gun carriages; namely, thoſe uſed in garriſons, at ſea aboard ſhips, and in the field. The two firſt differ only in ſome iron rings, and alſo that the trucks or wheels of garriſon carriages are made of caſt iron; whereas ſhip carriages are of wood; but the reſt of the conſtruction is the ſame.

Conſtruction

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Conſtruction of ſhip and garriſon carriages.

Plate V. Fig. 15.

In a line A B, take two points C, D, ſo as their interval be equal to the diſtance from the center of the trunions to the extremity of the breech, that is, equal to three ſevenths of the gun's length; through theſe points draw two lines at right angles to A B; in the firſt take C E, C F, each equal to half the diameter of the ſecond reinforce ring; and in the ſecond D G, D H, each equal to half the diameter of the baſe ring; then the lines drawn through the points E, G, and F, H, will determine the width within of the carriage.

If to theſe lines there be drawn two parallels at a caliber's diſtance, they will determine the breadth of the ſide pieces; and by ſetting off from D to B, the length of the caſcable, and from C to A, half the diameter of the trunions and half the diameter of the fore trucks; then will A B be the length of the carriage.

The line E F paſſes through the center of the trunion holes, which are a caliber, and whoſe center is a quarter of an inch below the upper ſurface of the ſide pieces. On each ſide of G H ſet off 6 inches for the breadth of the axletree, which is always 12 inches broad; and the fore part of the trunion holes is the center line of the fore axletree, whoſe dimenſions, as well as thoſe of the trucks, are given in the following table.

Fig. 16.

The height of the ſide pieces is 4¾ diameters of the ſhot before, and half that height behind; and if half the length of the ſide pieces be divided into four equal parts, beginning at the hind end, you will have the ſteps; the quarter-round is taken from the fore part. The lower part of theſe pieces is hollowed in the form

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of a circular arc, in order to make them ſomething lighter without diminiſhing their ſtrength. Both axletrees are ſunk into the ſide pieces in the manner repreſented in the 17th figure; and as to the tranſom, we chuſe to place it directly over the fore axletree, it is a diameter of the ſhot broad and two high, and placed exactly in the middle of the height of the ſide pieces; though it is cuſtomary to place the fore part in a line, paſſing through the center of the trunion holes, and ſo as to project the axletree by an inch, and the lower edge to touch the axletree.

Dimenſions of ſhip and garriſon carriages.

Nature of the gun,	42	32	24	18	12	9	6	3
Width inclosed { before	18	18	16. 5	15. 5	14	13	11. 5	9
Width inclosed { behind	23. 5	23. 5	22. 5	21. 5	19. 5	18. 5	16. 8	12. 5
Fore axletree length	57	57	54. 5	51. 5	45. 5	42. 5	38. 8	32. 5
Body { length,	35. 4	36. 6	34. 9	33. 1	29. 5	27. 5	24. 8	19. 5
Body { height,	10. 8	10. 8	10	10	10	9. 5	9	8. 5
Body { breadth,	6. 8	6. 8	6. 8	6	5. 5	5. 2	5	4
Arms { length,	10. 8	10. 2	9. 8	9. 2	8	7. 5	7	6. 5
Arms { diameter,	6. 2	6. 2	6. 2	5. 8	5. 2	5	4. 5	3. 5
Hind axletree length,	57	57	54	51. 5	45. 5	42. 5	38. 8	32. 5
Body { length,	35. 4	36. 6	34. 9	33. 1	29. 5	27. 5	24. 8	19. 5
Body { height,	6. 8	6. 8	6. 8	6	5. 5	5. 2	5	4
Body { breadth,	12	12	12	12	12	12	12	12
Fore trucks, { diameter,	19	19	18	18	16	16	14	14
Fore trucks, { breadth,	6. 5	6	5. 5	5	4. 5	4	3. 5	3
Hind trucks, { diameter,	16	16	16	15	14	14	12	10
Hind trucks, { breadth,	6. 5	6	5. 5	5	4. 5	4	3. 5	3
Side pieces { height before,	26. 8	26. 2	26	23. 6	20	18. 8	16	13. 6
Side pieces { length,	78	78	72	69	66	63	60	37. 5
Side pieces { breadth,	6. 5	6	5. 5	5	4. 5	4	3. 5	3
Trunions from the head,	8	8	8	8	6. 8	6. 6	6. 6	6

Theſe

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These dimensions are expressed in inches and decimals; and as the arms of the hind axle-tree have the same dimensions as those of the fore ones, they have been omitted, as well as the height behind the side pieces.

It may be observed, that these dimensions were used in 1748; but if the guns are made different from those at that time, the length and width of the carriages will likewise differ. The height of the side pieces and the diameter of the trucks depend on the height of the port-holes in ships from the deck. Those of the lower tiers ought to be such, that when the breech of a gun lies upon the hind axle-tree, the muzzle of the gun should touch above the port-hole, in order that it may not push the shutter open when the ship rolls in stormy weather.

General construction of carriages for new guns.

We suppose the diameter of the shot to be divided into 24 equal parts, as in the construction of the gun, so that the guns and their carriages may be constructed by the same scale; which is both more methodical and easier for the reader and the artillerest.

This being supposed; take C D equal to 6 diameters of the shot and 10 parts; and C E, C F, each equal to 34 parts, as likewise D G, D H, each equal to 39.5; the breadth of the side pieces is a diameter or 24 parts; D B to a diameter and 12 parts; A C to 2.5 diameters. The breadth of the fore axle-tree is 30 parts, its length $6\frac{1}{3}$ diameters; the length of the arms 44 parts, and their diameter 24. In the elevation, the height before of the side pieces is $4\frac{2}{3}$ diameters, and behind half that height; the height of the fore axle-tree is 42 parts, that of the hind one 30; the bed bolt passes under the middle of the fourth step, and even with the last or hind step.

The breadth of the wooden trucks is always equal to that of the side pieces, which is here one diameter or 24 parts; the diameter of the fore ones 4 diameters,

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and that of the hind 3 diameters and a half: but we have obſerved before, that if the port-holes in ſhips are made higher or lower, theſe diameters muſt be increaſed or diminiſhed.

The *French* make uſe of a carriage on board of ſhips with two trucks before only, and are preferred by many officers to thoſe of 4: I had ſome of them made, which ſeem to anſwer very well; they are nearly of the ſame height before as the common; but to leſſen the great height of the ſide pieces, the trucks are made of a larger diameter; they have no ſteps, and behind have a tranſom for the ſtool-bed to reſt upon inſtead of the body of the hind axle-tree. Theſe carriages do not recoil ſo much, and are more readily pointed, becauſe the trucks are not tight to their axle-tree. When they are traverſed but a little, the carriage will move without the truck, and then fall back again ſo ſoon as the hand-ſpike is taken away.

The *French* garriſon carriages are made much in the ſame manner; but the trucks are made larger and of ſeveral pieces, and have a trail like travelling carriages, but much ſhorter.

Fig. 17.

This elevation ſhews the inſide of the ſide pieces, with ſome of the irons, not elſe to be ſeen, and the manner we would have the ſide pieces let into the axle-trees, which is more ſimple, and yet equally as ſecure as the common manner, as likewiſe how the tranſom is to be placed, and not obliquely as the cuſtom is. The reſt of the figures in this plate ſhew the plans and elevations of the axle-trees and the ſtool-bed, as well as the tranſom.

Iron

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Irons for ſhip carriages.

a. Cape ſquares,	2
b. Eye bolts,	2
c. Joint bolts,	2
d. Tranſom bolt,	1
e. Bed bolt,	1
f. Bracket bolts,	2
g. Hind axle-tree bolts,	4
h. Breeching bolts with rings,	2
k. Burrs,	2
l. Loops,	6
m. Dowel pins,	4
n. Square rivetting plates,	8
p. Rings with keys,	10
q. Traverſing plates,	2
r. Linch pins,	4
s. Axle-tree hoops,	2
t. Axle-tree ſtays,	2
w. Keys, chains, and ſtaples,	2
x. Stool bed bolts with rivetting plates,	2

The garriſon carriages have the ſame irons, excepting the breech rings, and their trucks are of caſt iron; for which reaſon their axle-trees have copper clouts underneath, to diminiſh the friction of the iron againſt the wood.

Of travelling carriages. Plate VI. Fig. 19.

Previous to their conſtructions, it is neceſſary to mention the names of the ſeveral parts they are compoſed of, which are as follows. The long ſide pieces Q P, R S, are called the Cheeks; the fore part Q R of the carriage, the Breaſt; and the hind part P S, the Trail; T, the Trail Tranſom; V, the Center Tranſom; X, the Bed Tranſom; and Y, Breaſt Tranſom; G H, the

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Body of the Axletree; m, n, the Trunion Holes; and w, the Pintle Hole.

Dimenſions of the preſent cheeks.

Nature of the gun,	24	12	6	3
Length of the cheeks,	13	12	11	10
Thickneſs,	5. 8	4. 6	3. 6	3
Height of the plank,	22	19	16	13
Height of the cheek before,	20	17	14	11. 5
Height of the cheek center,	17	15	12	9. 5
Height of the cheek trail,	12	11	10	7. 5
Head from the center,	74	69	60	51. 5
Length of the trail,	18	15	12	10

Axle-trees.

Nature of the gun,	24.	12.	6	3
Body, length,	38. 5	39	40	40. 5
Body, breadth,	7	6. 5	6	5. 5
Body, height,	9	8. 5	8	7. 5
Arms, length,	21	20. 5	19	17. 5
Arms, body diameter,	7	6. 5	6	5. 5
Arms, linch diameter,	5	4. 5	4	3. 5
Total length	81	80	78	76

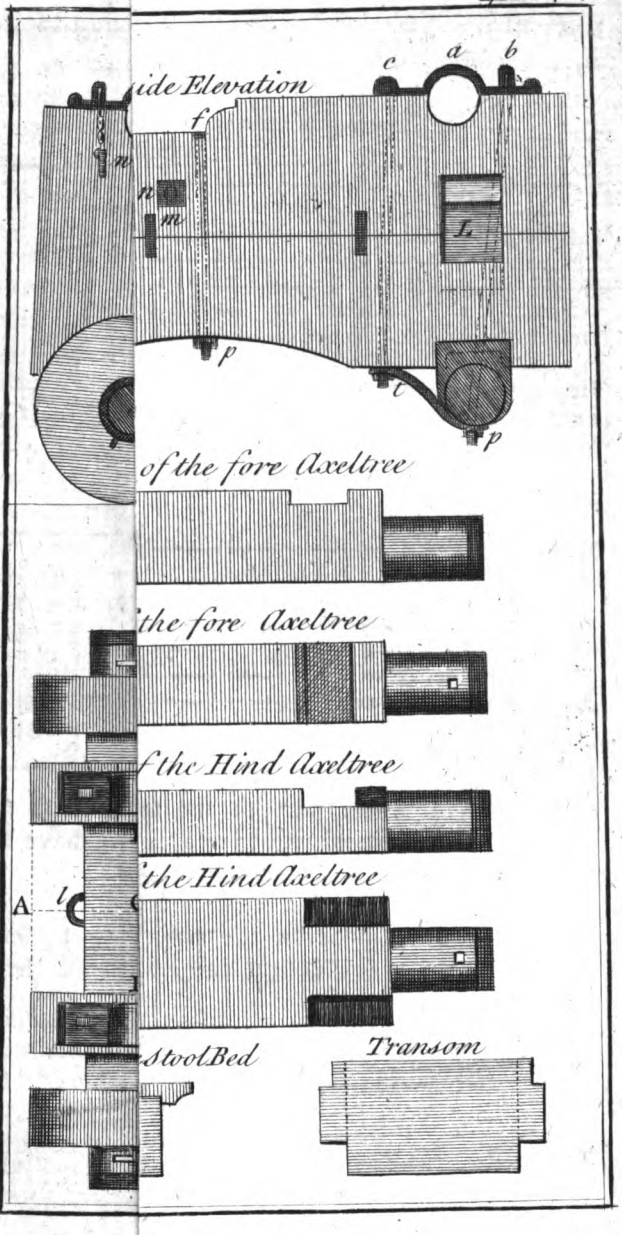
N. B. The under part of the axletree ſhould be in one continued right line, as we have ſhewn in our *Elements of Mathematics.*

All the dimenſions in the preceding tables are in inches and decimals, except the length of the cheeks, which are in feet.

Conſtruction of travelling Carriages. Plate VI. Fig. 18.

Let A b c d be the plank, and A B the height before of the cheeks; ſet off from B to C the ſum of the head A B, and the diſtance from the hind part of the

trunions



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trunions to the extremity of the caſcable; then from the point A as center, deſcribe an arc C D through the point C, on which as a chord ſet off the height at the center, and draw the lines A D, B C. On B C take B E, equal to the head A B, and towards the head E r, r S, each equal to half the diameter of the trunions, ſo that E S will be the width of the trunion hole, whoſe center is about a quarter of an inch below the line B C. From the point r draw r F, perpendicular to A D; in A D take F H, equal to the breadth of the axle-tree, which is ſunk about an inch into the cheeks. On the ſide F H make a ſquare, and from the interſection I of diagonals, as center, deſcribe an arc, with a radius of 29 inches, or equal to the radius of the wheel; this arc will repreſent a part of the wheel. Then if a ruler be laid ſo as to touch this arc, and cut the plank in two points M, L, ſuch that the diſtance M L be equal to the length of the trail, and you erect at theſe points two perpendiculars M N, L O, to K M, each equal to the height of the trail; by drawing the lines C N, N O, and D M, you will have the figure A B C N O L D A of the cheek required.

The part M P is made round, that the carriage may ſlide with more eaſe on the ground, which is done by dividing L O into four equal parts, ſo that L P be one of them, by drawing M P; and at the points M and P, erecting two perpendiculars on D M, and on M P, which meeting in Q, then the point R, which biſects M Q, will be the center of the arc M P required.

The mortiſe V of the center tranſom is determined by drawing a line through the point C, perpendicular to the horizon K M, in which C p is taken equal to a fourth part of the ſhot's diameter, and p q equal to two of theſe diameters for the height, and in p z, parallel to K M, the breadth p x equal to one diameter. The diſtance between the center and bed tranſom X is two diameters; this laſt is a diameter each way. The breaſt tranſom Y is a diameter broad and two high; the ſides

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are parallel to the head A B, and terminate above even with the bottom of the trunion hole one way, and when produced the inside meets the point S. Laſtly, the mortiſe T of the trail tranſom is equal in length to the trail, a diameter high, and is parallel to the upper ſide N O, ſo as when the lower is produced to meet the point P.

All theſe mortiſes are divided into four equal parts by horizontal lines; the upper part is ſunk half an inch into the cheeks; the two middle parts are ſunk to the depth of two thirds of the thickneſs of the cheeks, but the lower part is not ſunk in at all. They are made in this manner to prevent the wet from getting into the joint and rotting the tenons.

Conſtruction of the plan. Fig. 19.

Draw the indefinite line A B, in which take the points C, D, ſo as their interval be equal to the diſtance from the center of the trunions to the extremity of the baſe ring; through theſe points draw E F, K L, at right angles, to A B; make D K, D L, each equal to the radius of the baſe ring, and C E, C F, each equal to the radius of the ſecond reinforce ring; then the lines drawn through the points F, L, and E, K, will determine the width within of the carriage; if to theſe lines two others are drawn parallel, and at a diſtance equal to the length of the trunions, you will have the thickneſs of the cheeks Q P and R S.

On both ſides of the points E and F, ſet off half the diameter of the trunions, in order to have the trunion holes m, n; draw the breaſt tranſom Y of a diameter broad, ſo as the inſide be in a line with the fore part of the trunion holes; and if C A be taken equal to r B in the laſt figure, the line R Q at right angles to A B will determine the breaſt of the carriage, and the total length A B of the carriage is determined by the laſt figure.

If

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If you ſet off from the line K L two diameters for the length of the caſcable, you will have the hind part of the center tranſom V, whoſe width is a diameter as well as the bed tranſom X, and their interval is two of theſe diameters, as has been ſaid before; the trail tranſom T is determined as before by the length of the trail. In the middle of this tranſom is the pintle hole of an oval figure, wider above than below, that the pintle may have room to play on uneven ground.

The bed w is a board of an inch and a half thick, a foot broad, and ſunk into the bed and center tranſoms; the width of the axle-tree has been determined before, and its fore part paſſes through the centers of the trunion holes: there is a board fixed upon the axle-tree with one end, and the other upon the bed tranſom, which ſerves to lay hay or ſtraw upon for wadding.

Between the trail and center the breadth of the cheeks is diminiſhed on the inſide by a ſixth part, beginning at about a diameter from the trail, and ends within a diameter and a half from the center tranſom.

This is the common conſtruction of field carriages; but as it relates only to the four calibers, whoſe dimenſions have been given, the reader will ſtill be at a loſs how to conſtruct any other; and as the length of the cheeks depends not only on the caliber of the gun, but likewiſe on the height of the wheels, as well as on the length of the pieces, which varies very often: therefore, in the following conſtruction, we ſuppoſe the wheels of the common ſize, and the guns to be 20 or 21 diameters long, which is the common length at preſent of the 24 pounders.

General dimenſions of travelling carriages. Fig. 18.

The length A d of the plank is 12 diameters of the ſhot and 7.5 feet beſides; its height A b three diameters and three quarters; the height A B of the cheeks three diameters and a quarter; ſo that B b is half a diameter, the

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height D C at the center 70 parts of that diameter, divided into 24 equal parts, as in the conſtruction of guns; the length of the trail is three diameters, and its height M N two; the breadth F H of the axle-tree is two diameters, and the reſt of the dimenſions depend on the ſize of the gun.

General conſtruction of travelling carriages for the new guns.

Plate VI. Fig. 18.

The length A d of the plank is 10 diameters of the ſhot and 7.5 feet; its height A b, three diameters and three quarters; the height A b of the cheeks, three diameters and a quarter. Set off from B to C eight diameters, and twenty parts of that diameter divided into 24, as in the conſtruction of guns; then from the point A, as center, deſcribe an arc through the point C, on which, as a chord, ſet off 70 parts from C to D, and draw the lines A D, B C. On B C take B E, equal to the head A B, and towards the point B, the parts E r, r S, each equal to 9 parts, ſo that E S will be the width of the trunion holes, whoſe center is ſunk about a quarter of an inch into the cheek. From the point r draw r F, perpendicular to A D, and in A D take F H, equal to 30 parts for the breadth of the axle-tree, which is ſunk into the cheek about an inch. On the ſide F H make a ſquare, and from the interſection I of the diagonals, as center, deſcribe an arc with a radius of 29 inches, which arc will repreſent a part of the wheel. Now if a ruler be laid ſo as to touch this arc, and cut the plank in two points M, L, ſo that the diſtance M L be equal to three diameters, and there be erected at theſe points the perpendiculars M N, L O, to K M, each equal to two diameters, then, by drawing the lines C N, N O, and D M, you will have the outline A B C L D A of the cheeks. The under part of the trail is made round,

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round, and the mortiſes of the tranſoms are made as before.

Conſtruction of the plan. Fig. 19.

Draw the indefinite line A B, in which take the points C, D, ſo as their interval be 7 diameters and 17 parts; through theſe points draw E F, K L at right angles to A B; make D K, D L, each equal to 32.5 parts, and C E, C F, each equal to 27.5 parts; then the lines drawn through the points F, L, and E, K, will determine the width within of the carriage. If to theſe lines two others are drawn parallel, and at 18 parts diſtant, you will have the thickneſs of the cheeks, Q P and R S.

On both ſides of the points E F, ſet off 9 parts for the radius of the trunions, in order to have the trunion holes m, n. If C A be taken equal to r B in the laſt figure; the line R Q, drawn at right angles to A B, will determine the breaſt of the carriage, and the total length A B is determined by the laſt figure. The reſt of the conſtruction is the ſame as before.

Remarks on this conſtruction.

Regard muſt be had in the conſtruction of theſe carriages to their ſtrength, and that the piece may lay cloſe and ſteady in it; as likewiſe that the gun may be properly elevated, in caſe ricochet firing ſhould be required.

The thickneſs of the cheeks are here ſuppoſed eighteen parts inſtead of a caliber, as is uſual; this we eſteem ſufficient, becauſe pieces are now loaded with no more than one third of their ſhot's weight, or ought not at leaſt; which charge has been found ſufficient for battering pieces.

The length of theſe carriages is ſuch, that a 24 pounder may be elevated to about an angle of 9 degrees, and

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and the ſmaller ones to 10, or 11 and 12, which is more than ſufficient upon all occaſions. The cheeks are not bent too much at the center, becauſe, if they are, they become very weak in that part. We make the trunion holes ſo as one half of them is over the axle-tree, whereas the common practice is to make them juſt without, which, in my opinion, occaſions the weight of metal to hang too much beyond the center of the wheels.

Plate VII. VIII.

In theſe plates are the plan and elevation of a 6 pounder travelling carriage, with all the irons marked on them, ſuch as are now made.

Iron-work of travelling carriages.

Tranſom bolts with burrs	breaſt	1
	center	2
	trail	2
Tranſom plates with hooks	breaſt	2
	center	2
	trail	2
Trunion plates		2
Cap ſquares with joint bolts		2
Spring keys with chains and ſtaples		4
Eye bolts	fore	2
	hind	2
Breaſt plates		2
Plates with roſes	garniſh	2
	trail	2
Garniſh	bolts	2
	nails	6
Axle-tree bands		2
Side ſtraps		4
Draught rings with bolts and burrs		2
Locking plates		2
Laſhing rings with loops		8

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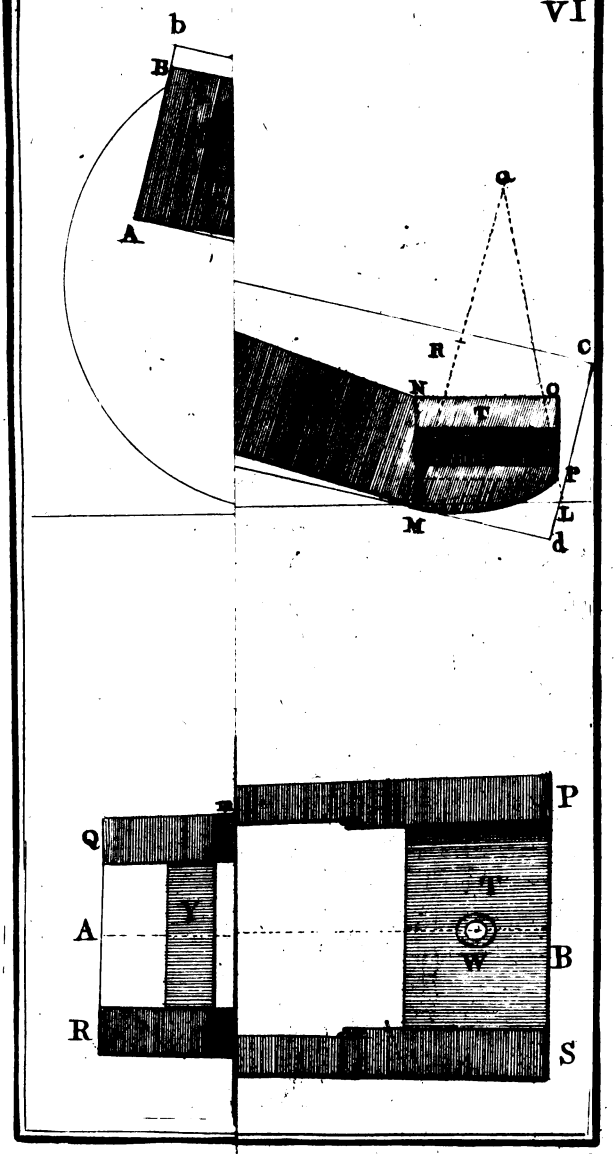
VI



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ASTOR, LENOX AND
TILDEN FOUNDATIONS

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Single forelock keys	8
Bed piece chain with ſtaple	1
Locker { hinges	2
Locker { haſp with ſtaples	1
Wood ſcrews	
Rivets	
Nails { roſebuds, diamond headed, counterſunk, trail	
Pintle plates upper and under	1

Names of the parts of a wheel. Plate IX.

A. Nave	1
B. Spokes	12
C. Fellies	6
n. Dowel pins	6
a. Streaks	6
b. Streak nails	48
c. Nave hoops	3
d. Nave boxes	2
f. Dowledges	6
g. Rivets for ditto	24
h. Nave hoop ſtubs	9
k. Box pins	6

The dowel pins are wooden pegs, of about three inches long, and three quarters of an inch in diameter; they ſerve to faſten the fellows together; and the dowledges are iron plates, faſtened and ſunk into the fellies on the outſide, ſo are not ſeen here; they ſerve to bind the joints of the fellies ſtrongly together, each with four pins.

The nave is always made of elm, cut ſix months before it is uſed, and left in the bark all the while till it is uſed; the ſpokes are made of elm or young oak, and uſed as dry and well ſeaſoned as poſſible; the fellies are likewiſe

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likewiſe made of dry elm, or in default of which young beech ſplit in two only will do as well, if not better; and the axle-tree is made of dry elm, young oak, or young beech.

The cheeks and tranſoms are always made of dry elm, on account that this wood is very pliable, receives the nails better than any other, and does not ſplit; yet I have ſeen ſome made of young oak, and am of opinion it is much ſtronger than elm, and I think may anſwer better.

Dimenſions of wheels for travelling carriages.

Caliber	24	22	6	3	Parts
Wheel, diam. inches	58	58	58	58	
Nave, length	17.5	17	15.5	15	76
Diameter body	15	15	13	12.5	62
Diameter middle	16	16	14	13	74
Diameter linch	13.5	13.5	10	10	60
Fellies thickneſs	5	4.5	4	3	22
Fellies breadth	6.5	6	5.5	4.5	28
Spokes thickneſs	2.3	2.2	2.1	2	10
Spokes breadth	4.5	4	3.5	3	20

The mortiſes of the ſpokes ſhould be placed in the middle of the nave, but the workmen make them an inch nearer to the linch. The ſpokes are ſomewhat leſs near the fellows than at the nave; they are likewiſe inclined towards the linch three inches in a wheel five feet high, and ſo in proportion in one of any other diameter; which the workmen call *diſhing*. How they found out that this inclination renders the wheels more perfect is not eaſily known; thoſe that I have converſed with knew no more than that it was an old cuſtom, which made me inquire farther into it, and I have found that it is grounded on true mechanical principles, as may be ſeen in my *Elements of Mathematics*, page 245.

The

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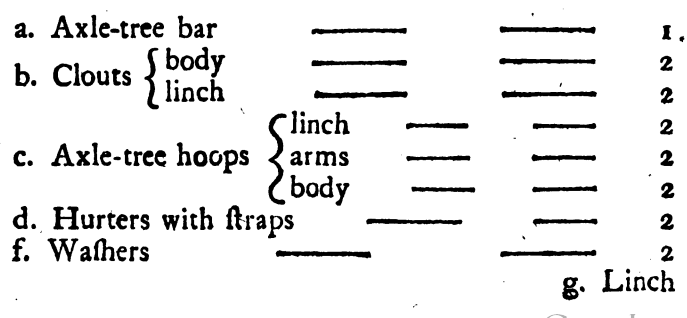
The laſt column in the preceding table contains the general dimenſions of the reſpective parts for wheels of any ſuch carriages, expreſſed by the parts of the diameter of the ſhot divided into 24, as in the conſtruction of guns, and proportional to the dimenſions of a wheel for a 24 pounder's carriage. Theſe general dimenſions are very uſeful in ſeveral reſpects: ſuppoſe it were required to make wheels for any other calibers than thoſe above, then you muſt either refer thereto, or elſe perform the work by gueſs. Again, theſe dimenſions being expreſſed by the ſame parts as the guns, they may both be conſtructed upon the ſame ſcale; which cannot be done in the common manner without a great deal of labour and difficulty: in ſhort, artillery would be incomplete without them; becauſe it is not ſufficient to know how to execute what has been done before, but any other work of the ſame kind that may be neceſſary.

The *Span*, or interval between the wheels, varies in different countries; even every county in *England* obſerves a different width, which is very inconvenient for thoſe who travel in carriages. The artillery carriages are made like thoſe in *Flanders*, which is four feet eight inches; but as the fellies are not of the ſame breadth in all wheels, we ſhall make the diſtance between the middle of the fellies five feet in all the carriages uſed by land, which are hereafter mentioned, the truck one excepted.

Iron-work of an axle-tree. Plate IX.



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g. Linch pins	———	———	———	2
h. Axle-tree bolt	———	———	———	1
k. Single forelock	———	———	———	2
Clout nails	——	——	——	12
Dog nails	——	——	——	8

Tools neceſſary to prove and load guns.

The ſearcher is an iron ſocket with branches, from four to eight in number, a little bent outwards, with ſmall points at their ends: to this ſocket is fixed a wooden handle, from 8 to 12 feet long, of about an inch and a quarter diameter. This ſearcher is introduced into the gun after it has been fired, and turned round, to diſcover the cavities within; and after their diſtances are marked on the outſide with chalk, they make uſe of another ſearcher, that has only one point, about which a mixture of wax and tallow is put to take the impreſſion of the holes; and if there are any of a quarter of an inch deep, or of any conſiderable length, the gun is rejected as unſerviceable to the government; though the iron is ſold to merchants. The gun is thus proved and ſearched twice.

The reliever is an iron ring fixed to a handle by means of a ſocket, ſo as to be at right angles: it ſerves to diſengage the firſt ſearcher, when any of its points are retained in a hole, and cannot otherwiſe be got out.

The worm is a double-wired ſcrew, fixed to a handle by means of a ſocket; it ſerves to draw out the wadding or bottoms of cartridges which remain in the gun after frequent firing, and which would otherwiſe accumulate ſo much, that other cartridges could not be rammed home enough to reach the priming, whereby the gun would miſs fire.

The ladle is made of copper, about three diameters of the ſhot long, and the thickneſs equal to the windage of the gun: it is of a cylindric form, having an opening above of about a ſixth part of the circle, and made like

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like a ſcoop at the end. The uſe of the ladle is to introduce the charge of powder into the gun, when it is not made up into a cartridge, or to looſen the ſhot, and draw it, in caſe it is retained by duſt got into the gun after much travelling.

The rammer is a cylinder of wood, whoſe diameter and length are each equal to the diameter of the ſhot, with a handle fixed to it; it ſerves to ram home the ſhot and powder when the gun is loaded.

The ſponge is likewiſe a cylinder of wood, from 10 to 12 inches long, of the ſame diameter with the rammer, and covered with lambſkin, ſo as to fit the gun exactly; it is commonly fixed to the other end of the rammer's handle in ſmall guns, but has a ſeparate one in thoſe of larger calibers. The uſe of the ſponge is to clean the piece before and after it is fired. The IXth plate repreſents the forms of theſe tools, whereby the reader may have a clear conception of them.

Guns are proved various ways, to find whether they are ſufficiently ſtrong; the moſt common in *England* is with a charge of powder, which weighs as much as the ſhot in all pieces under a 24 pounder; which, if braſs, is loaded with 21 pounds, the 32 pounder with 26 and 12 ounces, the 42 pounders with 31 pounds 8 ounces *; but in *France* they are charged with two thirds of the ſhot's weight only. Sometimes water is forced into them, but this proof is inſufficient; it has been found, that though the water penetrated through the piece in ſeveral places, yet they were very good and ſerviceable. The beſt and ſureſt way of proving pieces made after a new pattern, or of ſome new metal, is to charge them with no more powder than they are loaded with in action, and to fire them 2 or 300 rounds as quick as poſſible; and if they ſtand this trial, there is no danger of their

* The charge of the iron 24 pounder is 18 pounds; that of the 32 is 21 pounds 8 ounces; and the 42 is 25 pounds. As to the light braſs field pieces, they are proved with half the weight of the ſhot; except the 24 pounder only, with 10 pounds.

burſting

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burſting afterwards. This has been done by our light 6 pounders, when they were firſt introduced into our ſervice. Mr. *De Valliers*, lieutenant-general of the artillery in *France*, has propoſed another method for proving pieces, which is, inſtead of loading them with ſhot, to ram clay in as hard as poſſible two feet deep. But I doubt whether an iron cannon could ſtand ſuch a proof, nor would I adviſe the trial.

To conſtruct field carriages. Plate X.

As field pieces are ſhorter and much lighter than thoſe above, their carriages likewiſe obſerve the ſame proportion. They have the ſame form, but their wheels are only four feet two inches high; which, in my opinion, is too low; for the draught of low wheel carriages is known to be greater than the higher: and, though the guns are light, yet that is no reaſon to make the draught greater. I think, if they were 4.5 feet high, it would be much better; but it being no eaſy matter to change any thing eſtabliſhed by cuſtom, we ſhall inſert the dimenſions uſed at preſent, that the reader may ſee what has hitherto been the practice, leaving my obſervations to his judgment, either to approve or not, as he pleaſes.

Dimenſions of field carriages.

Calibers — --	24	12	6	Parts
Length of the plank	108	106	94	13 : 4
Height of the plank	15.6	14	12.4	3 : 6
Thickn. of the plank	4.5	3.7	3	0 : 18
Cheeks, height before —	14.5	12.7	11	2 : 18
Height at the center —	12	10.9	9.8	2 : 16
Height at the trail —	10	9.2	8.4	1 : 16
Length of the trail —	11	10.5	10	1 : 22
From head to center —	10	45	40	11 : 6
Width within before —	11.5	10.7	10	2 : 1
Width within behind —	17	15	13	2 : 15

Dimenſions

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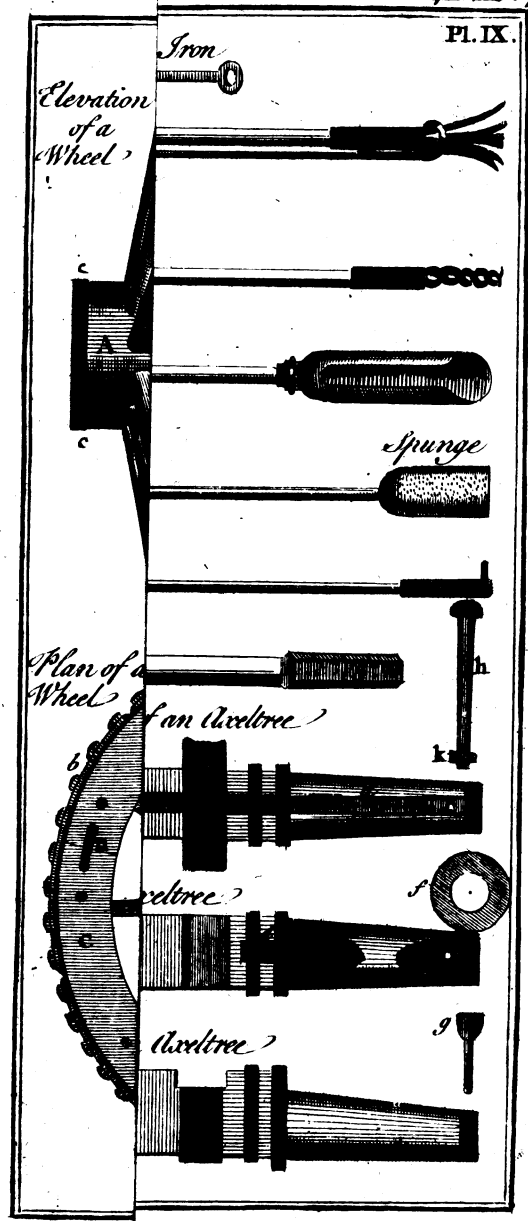

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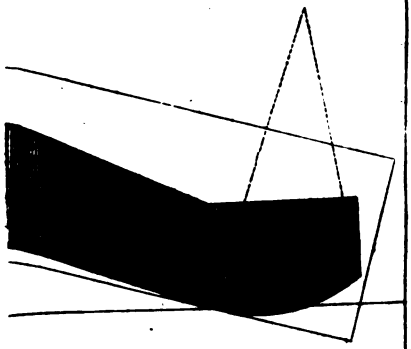

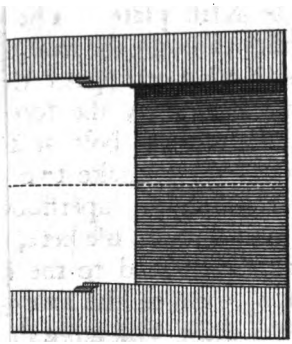

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There is one gun carriage more, which is called Galloper; it ſerves for a pound and an half gun. This carriage has ſhafts ſo as to be drawn without a limber, and is thought by ſome artilleriſts to be more convenient and preferable to other field carriages: and as it may likewiſe ſerve for our light three and ſix pounders, we ſhall give the following

Dimenſions of a galloper carriage. Plate XII.

	Feet.
Total length of the ſhafts,	11 : 0
From the fore end to the fore croſs bar,	6 : 4
From the hind end to the round part,	5 : 0
Height at the hind end,	0 : 6
Height at the fore end,	0 : 3
Breadth behind and before,	0 : 3.5
Breadth in the middle,	0 : 4.5
Width within behind,	2 : 6.5
At the fore croſs bar,	2 : 4
At the fore end,	2 : 1
From the hind end to the axle-tree,	0 : 11
Croſs bar from the hind end,	0 : 3
Length of the cheeks,	4 : 2
Breadth of the cheeks,	0 : 2.5
Height of the cheeks,	0 : 6.5
Width within before,	0 : 8
Width within behind,	0 : 11.5
Total length of the axle-tree,	6 : 4
Length of the body,	3 : 6.5
Length of the arms,	1 : 4.6
Breadth of the body,	0 : 5
Height of the body,	0 : 6
Greateſt diameter of the arms,	0 : 5
Leaſt diameter of the arms,	0 : 3.3
Diameter of the wheel,	4 : 3
Nave, length,	1 : 1

Diameters, body,		0 : 11
middle,		1 : 0
linch,		0 : 10
Spokes, breadth,		0 : 1.5
thickneſs,		0 : 3
Fellows breadth,		0 : 3
height,		0 : 4.5

The dimenſions not inſerted here may be taken from the draft.

Of Limbers. Plate XIII.

A limber is a two wheel carriage with ſhafts, and ſerves to ſupport the trail of field carriages, by means of the pintle or iron bolt, when they are to be drawn from one place to another; they are taken off again when the pieces are to be fired. Their dimenſions are,

Caliber,	24	12	6	3
	Inches			
Wheels diameter,	48	48	48	45
Nave length,	16	15	14	10
Diameters body,	13.6	13.6	12	12
middle,	14	14	13	12.5
linch,	12	12	11	10
Fellows breadth,	4.5	4	3.5	3
height,	5	4.5	4	3.5
Spokes breadth,	1.8	1.6	1.4	1.2
thickneſs,	4	3.5	3	2.5
Axle-tree length,	78	76	74	69
Body length,	40	40	40	45
height,	7.6	7	6	5.5
breadth,	6	5.5	5	5
Arms length,	19	18	17	13
Diameters body,	5	4	4	4
linch,	4	3	3	3
Shafts length,	94	94	94	94

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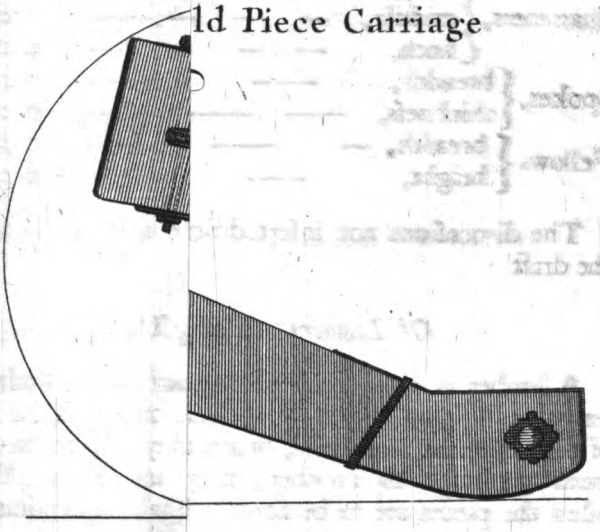
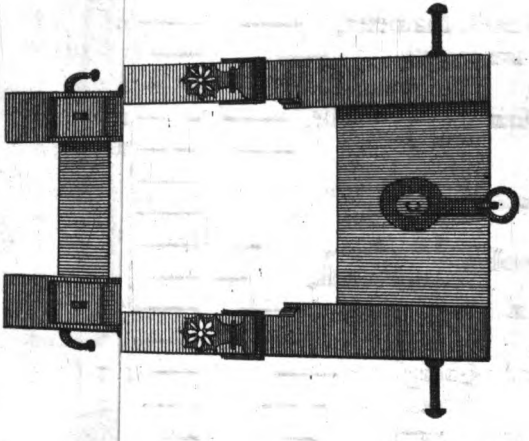
1d Piece Carriage





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ASTOR, LENOX AND
TILDEN FOUNDATIONS

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Breadth { hind end,	6	5. 5	5	4
Breadth { fore end,	3	3	2. 5	2. 5
Height { hind end,	3. 3	3	3	3
Height { fore end,	3	3	2. 5	2. 5
Bolſter height,	12. 5	10	8	7
Length,	40	40	40	43
Breadth,	6	5. 5	5	5
Fore croſs bar { breadth,	4. 5	4	3. 5	3
Fore croſs bar { height,	1. 5	1. 5	1. 5	1. 5
Hind croſs bar { breadth,	3. 5	3. 5	3. 5	3
Hind croſs bar { height,	1. 5	1. 5	1. 5	1. 5
Axle-tree from the fore croſs bar,	11. 5	11. 5	11. 5	11. 5

All ſhafts are about two feet open before, two feet ten inches in the middle, and ſomething leſs near the axle-tree, according as the wood happens to be more or leſs crooked; for it is never cut acroſs the grain, becauſe that would weaken it too much. The bolſter diminiſhes towards both ends, as in the drafts; ſo that the height given here is to be meaſured in the middle.

Iron work of the ſhafts.

a. Limber bolt,	1
b. Shaft rings,	2
c. Shaft pins with chains,	2
d. Breech hooks,	2
e. Ridge chain with hook and loop,	1
f. Limber chain with hook and rings,	1
g. Single forelock keys,	4
h. Nails, diamond headed,	8
k. Dog nails,	6
l. Bolſter hoops,	2
m. Pintle,	1
n. Pintle waſher,	2
Stubs for bolſter hoops,	8

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The iron work of the wheels and axle-tree being the ſame as before, only lighter in proportion to the wooden work, we think a repetition needleſs.

REMARKS.

The wheels of the limbers being but four feet high, and the extremities of the ſhafts five, the draught of the ſhaft horſe becomes ſo oblique, that the greateſt part of his force is loſt in ſupporting the fore ends of the ſhafts, which the other horſes draw down again, ſo as to bring the whole draught in a right line from the axle-tree to the breaſt of the fore horſe; whereby the ſhaft horſe is ſo ſhook (the difference between the height of the fore end of the ſhafts and the center of the axle-tree being at leaſt two feet) that he is ſpoiled in a ſhort time, and rendered unfit for ſervice: on the other hand, the bolſter of a 24 pounder limber is 14 inches high from the center line of the axletree; when the carriage is moving, it endeavours to turn the limber about its axis, and the trail would ſlip out of the pintle, were it not for the limber chain that retains it. All theſe oblique motions being conſidered, it will be found by thoſe converſant in mechanic principles, that worſe cannot be contrived. It is very difficult to contrive better: for the trails of field carriages cannot be altered; and if the wheels were made higher and the bolſter lower, the carriage cannot turn ſo well in a narrow road, nor can the trail be fixed under the axle-tree for the ſame reaſon: the only remedy that can be found, in my opinion, would be to fix a pole or ſhafts in ſome way or other to the head of the carriage, ſo as to draw it forwards, and the trail to ſlide on the ground like a ſledge; but how this may be done muſt be left to ſome ingenious workman.

PART

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PART V.

Of mortar beds and howitz carriages.

THE land mortar beds are here made of ſolid timber, conſiſting generally of four pieces; thoſe of the royal and coehorns excepted, which are but one ſingle block. As to ſea mortars, their beds are made quite different from theſe, as will be ſhewn each in their order.

Dimenſions of land mortar beds. Plate XIV.

Bore,		13	10	8	5.8	4.6
		Inches				
Lower bed	length,	84	66	50	0	0
	breadth,	33	20	0	0	0
	height,	13	10	9	0	0
Upper bed	length,	83	65	49	31.5	28.6
	breadth,	32	25	19	16	14
	height,	13	12	11	10	9
Breadth quarter round,		3	2.5	2.5	0	0
Of the ogee and fillet,		4	3.5	3	0	0
Length of the cavity,		20	16	12	8	5.7
Trun. hole from fore end,		31	20	15.5	13.3	11.7
Diam. of trun. holes,		7.2	6.4	5.4	3.4	2.4
Depth of trun. holes,		7	6	5	3.2	2.2

The diſtance of the trunion holes is meaſured from the quarter round, and not from the end of the bed. The joint of the two pieces of the upper bed, in the 13, 10, and 8 inch beds, are ſo contrived as not to be directly over the joint of the pieces in the under bed.

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Names and number of irons in a 13, 10, and 8 inch bed.

a. Cap ſquares,	2
b. Eye bolts,	2
c. Joint bolts,	2
d. Under and upper bed bolts,	9
f. Dowel bars,	4
g. Rings with bolts,	4
h. Reverſe bar,	2
k. End rivetting plates,	2
l. Middle plate,	1
m. Rivetting bolts,	6
n. Square rivetting plates,	12
p. Traverſing bolts,	6
q. Keys, chains, and ſtaples,	2

Names and number of irons in a royal and coehorn bed.

a. Cap ſquares,	2
b. Eye bolts,	2
c. Joint bolts,	2
d. Rivetting bolt with ring,	1
f. Handles with ſtarts,	2
g. Square rivetting plates,	5
h. Keys, chains with ſtaples,	2

Dimenſions

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Dimenſions of beds for the three new mortars.

Diameter of the bore, —		30		30		30
Lower bed	length, —	6 : 0		5 : 10		4 : 25
	breadth, —	2 : 10		2 : 2		1 : 26
	thickneſs, —	0 : 28		0 : 25		0 : 22.5
Upper bed	length, —	5 : 28		5 : 8		4 : 23
	breadth, —	2 : 8		2 : 0		1 : 24
	thickneſs, —	0 : 28		0 : 25		0 : 22.5
Breadth of the ogee, —		0 : 6		0 : 5		0 : 4.5
Of quar. round and fillet,		0 : 6		0 : 5		0 : 4.5
Diam. of trun. holes		0 : 14		0 : 13		0 : 12
Depth of trun. holes		0 : 10		0 : 9.5		0 : 9
Interval between them, —		1 : 5		1 : 5		1 : 4
Their length, — —		0 : 15		0 : 14		0 : 13

The firſt numbers in each column expreſs the diameters of the bore, and the ſecond the parts of that diameter divided into 30, as in the conſtruction of mortars. The center line of the trunion hole paſſes through the middle of the upper bed.

The dimenſions of the firſt of theſe beds will hold nearly true in regard to the preſent mortars. As to thoſe uſed at preſent, there is no proportion between them; ſome are larger and others ſmaller than they ſhould be; for it has been obſerved, that when the royal and coehorn are fired, their beds kick about very much, which is a certain ſign that they are too ſmall. We have obſerved before, that the mortars both here and in *France* are not conſtructed by any rule; the ſame is true in regard to their beds; and it is no wonder, ſince *St. Remy*, the only author who has wrote a complete treatiſe upon artillery, did no more than copy ſuch memoirs as he received from the workmen, without pretending to reaſon upon the ſubject, and in all appearance was not qualified for it.

General

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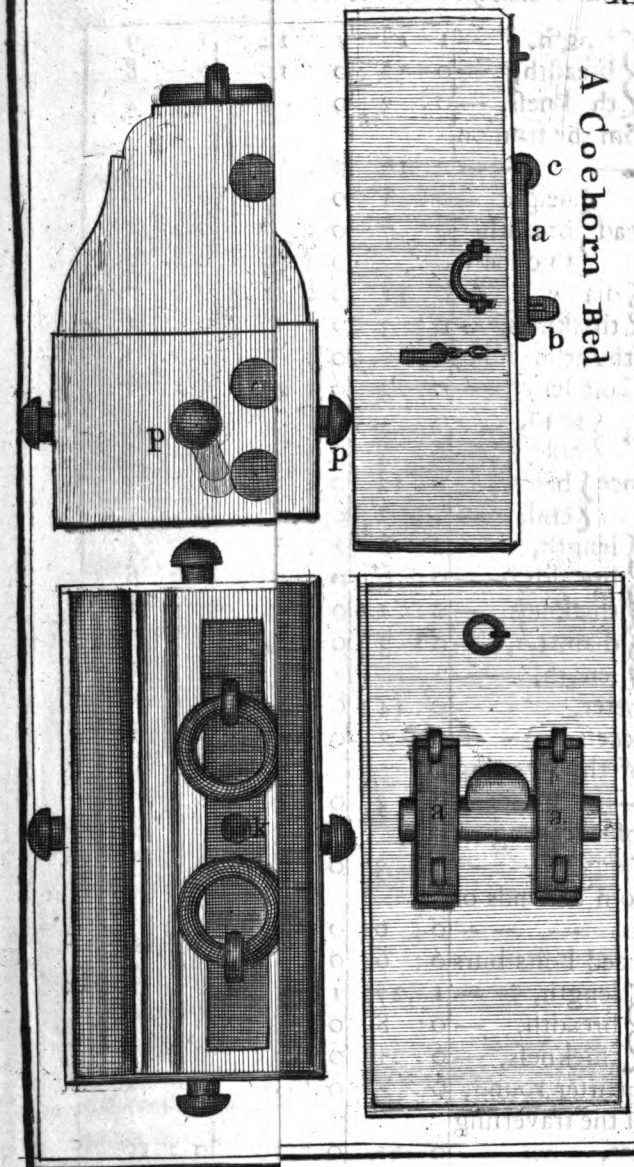
General dimensions of the iron work.

Cap square { length,	1 : 18	1 : 14	1 : 9
Cap square { breadth,	0 : 12	0 : 10	0 : 8
Cap square { thickness,	0 : 3	0 : 2.5	0 : 2
Fore end from the trunion hole,	0 : 16	0 : 14	0 : 13
Eye bolt head { height,	0 : 8	0 : 7	0 : 6
Eye bolt head { breadth,	0 : 7	0 : 6	0 : 5
Eye bolt head { thickness,	0 : 3.5	0 : 3.5	0 : 3
Joint bolt head { diameter,	0 : 11	0 : 8.5	0 : 7.5
Joint bolt head { thickness,	0 : 3.5	0 : 3.5	0 : 3
Dist. from the trun. hole,	0 : 10.5	0 : 9.5	0 : 7.5
Traversing bolt length,	0 : 23	0 : 20	0 : 16
Diameter of { head,	0 : 4.5	0 : 3.5	0 : 3
Diameter of { bolt,	0 : 3	0 : 2	0 : 2
Their distance from { below,	0 : 12	0 : 11	0 : 10
Their distance from { end,	1 : 2	0 : 29	0 : 24
Mid. plate { length,	2 : 8	2 : 0	1 : 24
Mid. plate { breadth,	0 : 9	0 : 7	0 : 6
Mid. plate { thickness,	0 : 1.6	0 : 1.5	0 : 1.5
Bed bolt { diameter,	0 : 3	0 : 2.5	0 : 2
Bed bolt { length,	2 : 10	2 : 2	1 : 26
Ring { diameter,	0 : 14	0 : 12	0 : 10
Ring { thickness,	0 : 3	0 : 2.5	0 : 2
Diameter of the rivetting bolts,	0 : 3	0 : 2.5	0 : 2
Diameter of the ring rivetting bolts,	0 : 3	0 : 2.5	0 : 2
Distance from the ends of the plates,	0 : 6	0 : 5	0 : 4
Dia. of the bed bolts burs	0 : 6	0 : 5	0 : 4
Rivetting plates { length,	1 : 27	1 : 19	1 : 14
Rivetting plates { breadth,	0 : 8	0 : 6	0 : 5
Rivetting plates { thickness,	0 : 1	0 : 1	0 : 1
From the quarter round,	0 : 8	0 : 6	0 : 5
Diameter of the traversing bolt plates,	0 : 11	0 : 10	0 : 10

We

XIV

A Coehorn Bed



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We ſuppoſe theſe mortars ſo fixed in their beds as to be moveable, quite contrary to the preſent practice, and that they may be raiſed from an angle of 10 degrees to any under 90; for which reaſon the depth of the trunion hole is not equal to its diameter, and the cavity in the bed is to be made in ſuch a manner as to receive the wedges by which the mortar is raiſed.

Dimenſions of ſea mortar beds. Plate XV, XVI.

	13	10
Diameter of the bore,		
Length of the bed,	94	84
Breadth of the bed,	54	47
Height of the bed,	27	23
Pintle hole from the fore end,	39	32
Diameter of the pintle hole,	6. 5	6. 5
Trunions from the fore end,	46	42. 5
Diameter of the trunion holes,	10	8
Depth of the trunion holes,	8	5
Diameter of the circular bed,	59	59
Height of the circular bed,	8	6
Diſtance to the bed bolſter,	15	16
Depth of the cavity,	15	12
Its opening above,	30	21
Bed bolſter length,	53	44
Length below,	29	2. 1
Its height,	16	17
Its breadth,	14	12

Theſe beds are placed upon very ſtrong timber frames, fixed into the bomb ketch, to which the pintle is fixed ſo as the bed may turn about it. The fore part of theſe beds is an arc of a circle deſcribed from the ſame center as the pintle hole. The plans, elevations, and different ſections ſhew in a diſtinct manner the ſeveral parts of theſe beds.

Iron

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Iron work of theſe beds.

a. Cap ſquares,	2
b. Eye bolts,	6
c. Loop bolts,	4
d. Traverſing bolts,	4
e. Middle plate,	1
f. Riveting plates,	1
g. Riveting bolts,	6
h. Croſs bed bolts,	7
l. Square riveting plates for ditto,	7
k. Down bed bolts,	15
m. Bed bolſter plates,	2
Keys, chains and ſtaples,	6
Nails to the bed bolſter bed,	4
Bed bolſter rings with loops,	2

Dimenſions of an eight inch howitz carriage. Plate XVII.

Length of the cheeks,		101
Thickneſs,		4.5
Height before,		18
Height at the	center,	16
	trail,	14
Length of the trail,		15
Height of the plank,		18
From the head to the center,		43
Trunion holes from the head,		9
Breaſt tranſom	length,	14.5
	height,	
	thickneſs,	4.5
Center tranſom	length,	16.5
	height	
	thickneſs,	4.5
Trail tranſom	length,	19
	breadth,	15
	thickneſs	

The

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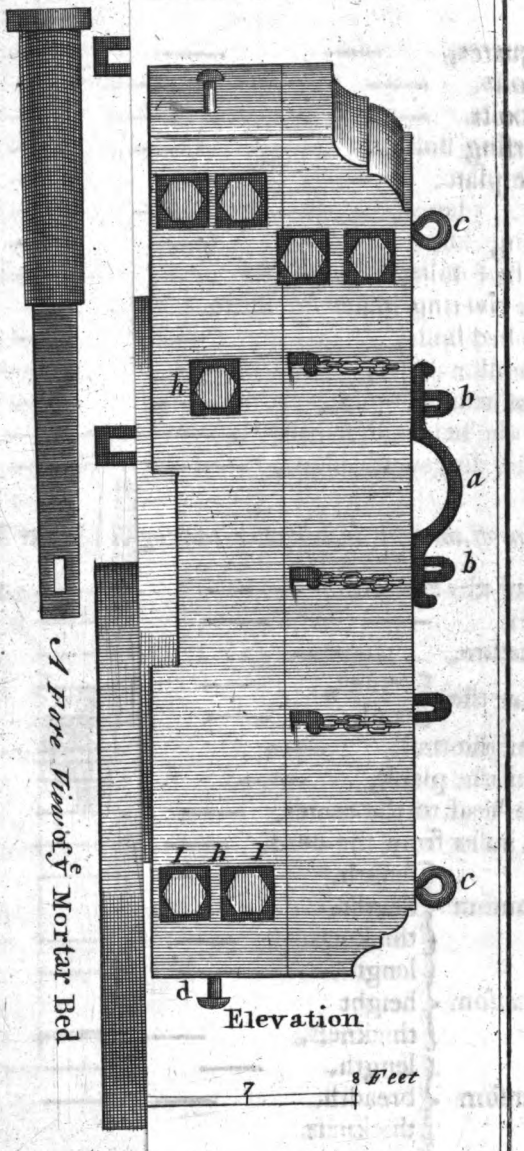
XVI



A Fore View of y^e Mortar Bed

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The iron work of these carriages is the same as in field carriages; but there are only four garnish nails, two of a side, because they are so short as not to admit of more. As to the wheels and axle-tree they are the same as in an 18 and 12 pounder's carriage.

PART VI.

Of different sorts of carriages used in the artillery.

Dimensions of a Tumbrel. Plate XVIII.

	Inches.
Diameter of the wheel,	60
Nave length,	15
Diameters { body,	12
Diameters { middle,	13
Diameters { linch,	10
Spokes { breadth,	2. 2
Spokes { thickness,	3. 3
Fellows { breadth,	4. 5
Fellows { thickness,	3. 5
Axletree length,	76
Body { length,	42
Body { breadth,	5.
Body { height,	6. 7
Arms length,	17
Diameters { body,	4. 5
Diameters { linch,	3
Shafts total length,	147
From the hind { end to the cross bar,	7
From the hind { cross bar to the fore cut,	62
From the fore cut to the fore end,	78

Breadth,

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		Inches.
Breadth	behind	4
	at the fore cut	4. 6
	in the middle	3. 5
	at the fore end	2. 3
Height from the hind end to the fore cut		3. 5
Height at the fore end		2. 3
Width within	behind, and at the fore cut	34
	in the middle	35
	at the fore end	25
Croſs bars	breadth	3. 5
	thickneſs	2
	length	31
Fore cut	length	51
	breadth	4
	thickneſs	2
Raves	length	62
	breadth	2
	thickneſs	3
Standards	length	24
	breadth	2. 8
	thickneſs	1. 3
Head bars	length	36
	breadth	1. 2
	thickneſs	1. 8
Uprights	length	22
	breadth	1. 3
	thickneſs	3

Iron work of a tumbrel.

A pair of wheels and axle-tree compleat.	
Axle-tree pins with rings and keys	2
Fore cut pins	2
Breech hooks	2
Shaft rings	2
Shaft pins with chains and ſtaples	2
Ridge chain with hook and loop	1
Bail ſtaples	6

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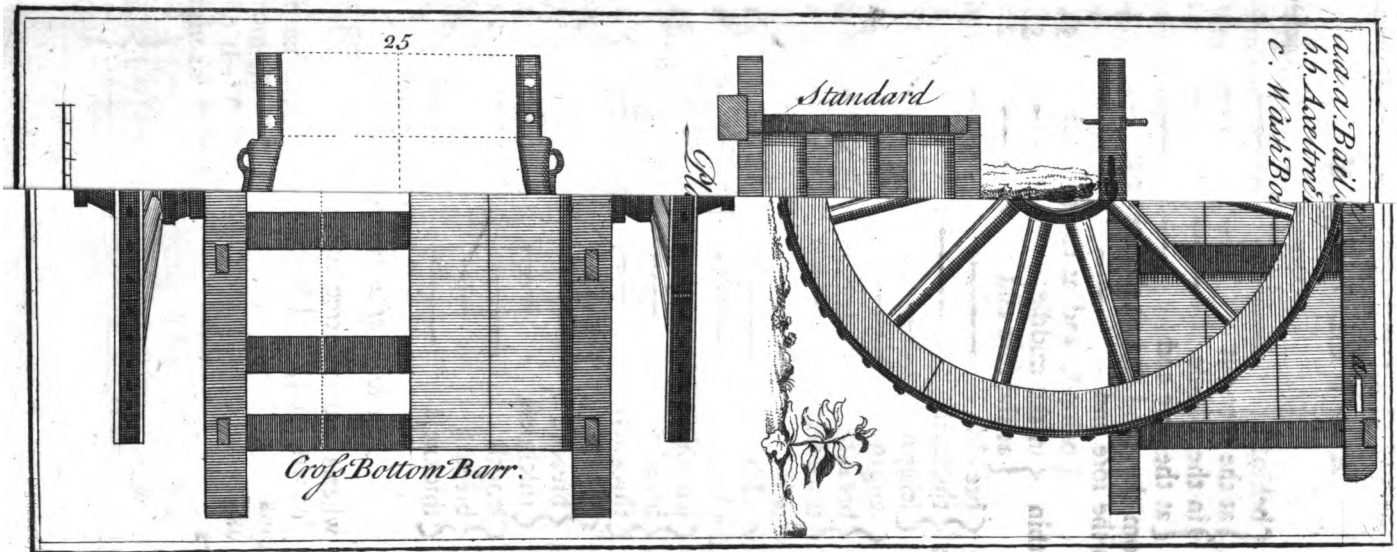
25
Standard
Cross Bottom Barr.
a.a. Bails
b.b. Axeltree
c. Wash Boa

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The common uſe of tumbrels is to carry the pioneers and miners tools; but they ſerve likewiſe to carry the money of the army.

Dimenſions of a powder cart. Plate XIX.

The wheels and axle-tree are the ſame as in the tumbrel, except the height of the wheels is here 5.5 feet.

		Inches.
Sides with ſhafts, total length		180
From the hind	end to the croſs bar	5.5
	croſs bar to the fore croſs bar	88.5
From the fore croſs bar to the fore end		77.5
Breadth	behind	3.3
	fore croſs bar	4.4
	middle	3.7
	before	2.8
Height	behind	3
	fore croſs bar	4
	before	2.8
Opening behind, and at the fore croſs bar		34
At	middle	35
	before	25
Two ſhaft croſs bars	length	34
	breadth	2
	height	3
Under croſs bars	length	40
	breadth	3
	height	2
Side pieces	length	100
	breadth	13
	height	3
The axle-tree paſſes through the ſide pieces from the bottom		3
From the ſhafts to the beginning of the roof		6
Height of the roof		12
Lids	length	88
	breadth	10
	thickneſs	1

Roof

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		Inches.
Roof lids	length	88
	breadth	11
	thickneſs	1

The roof is covered with oil cloth to prevent dampneſs from coming to the powder, and each ſhot locker is divided into four parts by boards of an inch thick, which enter about an inch into the ſhafts. Each of theſe carts can ſtow four barrels of powder only.

Iron work of a powder cart.

a. Side bolts with ſcrews	8
b. Croſs bolts with ſingle keys	2
c. Double hinges for the ſhot lids	6
d. Staples and keys with chains	4
e. Hinges for roof lids	2
f. Haſps, ſtaples, and keys for ditto	3
g. Axle-tree pins with keys	2

Compleat irons for ſhafts, wheels, and axle-tree.

Dimenſions of an ammunition waggon. Plate XX.

		Inches.
Fore wheels, height		48
Nave, length		13
Diameter	body	12
	middle	14
	linch	10
Fellows	breadth	3
	height	4
Spokes	breadth	1. 5
	thickneſs	3
Hind wheels, height		60
Nave, length		13
Diameters	body	12
	middle	14
	linch	10

Fellows

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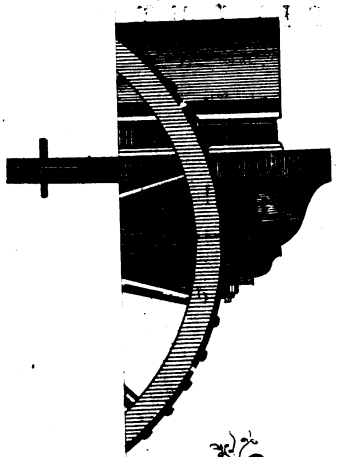
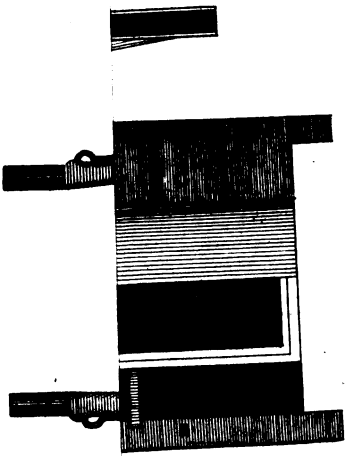
XIX





Feet 6

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		Inches.
Fellows	breadth	3
	height	4
Spokes	breadth	1. 8
	thickneſs	3. 5
Fore axle-tree, total length		72
Body	length	40
	breadth	5
	height	6
Arms, length		16
Diameters	body	5
	linch	3
Hind axle-tree, total length		70
Body	length	38
	breadth	5
	height	6
Arms, length		16
Diameters	body	5
	linch	3
Fore bolſter	length	49
	breadth	5
	height	6
Hind bolſter	length	46
	breadth	5
	height	6
Rider	length	49
	breadth	5
	height	4. 7
Sommers and ſides	length	144
	breadth	3
	height	3
Pole	length	120
	ſquare before	4
	ſquare behind	3
Middle bar	length	40
	breadth	3. 5
	height	6. 5

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		Inches.
Hind guide	length to the axle-tree	28
	breadth at the head	5
	ſquare at the axle-tree	3
	opening at the axle-tree	24
Fore guide	length to the axle-tree	32.5
	breadth before	5
	breadth behind	4
	thickneſs	3
Length of the ſtraight part		20
Length from the axle-tree to the hind end		28
Opening	to receive the tong	4
	near the axle-tree	19
	behind	40
Sweep bar	length	50
	breadth	3.5
	height	2.5
Raves	length	144
	breadth	2.2
	height	2.2
Flate ſtaves	length	15.5
	breadth	2.5
	thickneſs	1
Shafts length		67
Length of the ſtraight part		10
Breadth	behind	3.2
	at the fore ſhaft bar	5
	before	3
Thickneſs before		3
Opening	at the ſhaft bolt	15
	at the fore ſhaft bar	21
	in the middle	30.5
	before	24
Shaft bars	breadth	3
	thickneſs	2
Tong	length	17
	breadth	3.6
	thickneſs	3

Length

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	Inches.
Length of the guide bar	50
Breadth in the middle	3
Breadth at the end	1. 5
Thickneſs	1. 5
Diſtance from the center of one axle-tree to the other	89

The ſommers go 10 inches beyond the fore axle-tree, and 38 beyond the hind.

Iron work of an ammunition waggon.

Pintle	1
Pole pin	1
Bolſter pins with keys	4
Locking plates	2
Bail ſtaples	16
Sweep bar pins	2
Shaft bolt with key	1
Swing tree pins	2
Hooks for ditto	2
Bars to fix the ſwing-tree to the axle-tree	2
Plate for the croſs bar of the fore guide	1
Waſhing plates for the ſhafts	2
Bolſter bands	4
Pole plate	1

Irons compleat for ſhafts, axle-trees, wheels, dowledges excepted.

This waggon ſerves likewiſe to carry bread, it being lined round in the inſide with baſket work.

Dimenſions of a block carriage. Plate XXI.

	Inches.
Fore wheels, height	48
Nave, length	15
Diameters body	14
Diameters middle	15
Diameters linch	13

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		Inches.
Fellows	height	5. 5
	breadth	3. 5
Spokes	breadth	2
	thickneſs	3
Hind wheels, height		60
Nave, length		17
Diameters	body	14
	middle	15
	linch	13
Fellows	height	6. 5
	breadth	4
Spokes	breadth	2. 3
	thickneſs	4
Fore axle-tree, total length		77
Poly	length	39
	breadth	6. 5
	height	8
Arms, length		19
Diameters	body	6
	linch	4
Bolſter	length	49
	breadth	6. 5
	height	7
Hind axle-tree, total length		77
Body	length	37
	breadth	7
	height	8. 7
Arms, length		20
Diameter	body	6
	linch	4. 8
Bolſter	length	47
	breadth	7
	height	8
Side pieces	length	132
	breadth	6. 5
	height	6. 5
Diſtance between the axle-trees		72

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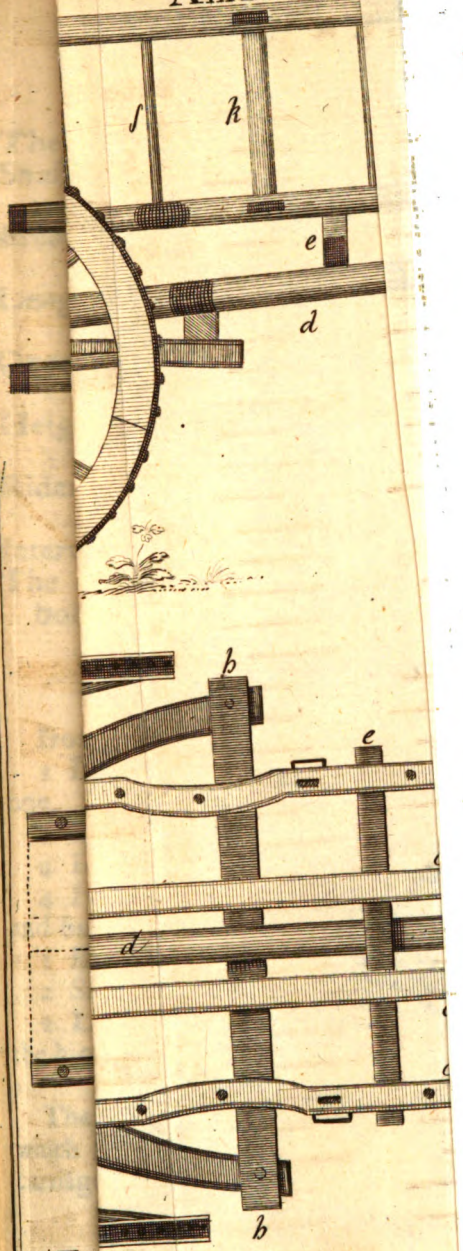

Feet

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	Inches.
The ſide pieces project equally by	24
Shafts, length	96
Breadth behind	5. 3
Breadth in the middle	6
Breadth before	3
Length of the ſtraight bar	19
Opening behind	28. 5
Opening middle	32. 5
Opening before	24
Height of the ſhafts	3
Rider length	46
Rider breadth	6. 5
Rider height	8
Interval between the ſide pieces	12
The ſide pieces are let into the rider and hind bolſter	2

Iron work of a block carriage.

Irons compleat for wheels, axle-tree, and ſhafts.

1 Iron bar to faſten the hind axle-tree to the fore one.

2 Bolts to fix this bar to the axle-trees.

4 Bolſter bolts.

4 Hooks faſtened to the ſide pieces with two bolts and burs.

1 Bar to faſten the ſide pieces in the middle.

2 Staples for ſhafts, and two iron bands with loops.

2 Loops, one faſtened to the rider, and the other to the hind bolſter.

The uſe of this carriage is to carry guns in the field, which are too heavy to be tranſported upon their own carriages, as likewiſe mortars and their beds.

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Dimenſions of a ſling waggon. Plate XXII.

		Inches.
Side pieces	length	152
	breadth	6
	height	7. 8
	opening	32
	exceed, axle-tree	10
Interval between the centers of the axle-trees		123
Fore wheel, height		48
Nave, length		14
Diameters	body	13
	middle	14
	linch	11
Fellows	breadth	3. 8
	height	55
Spokes	breadth	2. 2
	thickneſs	3. 5
Hind wheel height		68
Nave, length		17
Diameter	body	16
	middle	17
	linch	13
Fellows	breadth	4. 4
	height	6
Spokes	breadth	2. 2
	thickneſs	4
Fore axle-tree, length		75. 5
Body	length	41. 5
	breadth	5
	height	8
Arms, length		17
Diameter	body	5
	linch	3
Hind axle-tree, length		81
Body	length	41
	breadth	5
	height	7

Arms,

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		Inches.
Arms, length		20
Diameter	body	5
	linch	4
Fore bolſter	length	41. 5
	breadth	5
	height	12
Hind bolſter	length	51
	breadth	5
	height	11
Rider	length	54
	breadth	5
	height	7. 2
Cheeks to ſupport the rack work	length below	60
	length above	22
	height	20
	breadth	6
Shafts, length		94
Breadth	behind	5. 5
	middle	4
	before	3
Opening	behind	23
	middle	34
	before	25
Thickneſs of the ſhafts		3

Iron work of a ſling waggon.

2 Cap ſquares.
4 Eye bolts.
2 Trunion plates.
2 Beam hooks.
1 Iron to faſten the tooth wheel.
Rack work with pland and handle.
An iron bar to ſtop the jack.
8 Bolts with ſcrews to faſten the cheeks to the ſide pieces.
2 Hind axle-tree ſtays with bolts.

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A croſs bar to faſten the ſide pieces together.

4 Hooks faſtened to the ſide pieces with bolts and burs.

4 Bolſter bolts with rings and keys.

Pintle with band and waſher.

4 Bolſter hoops.

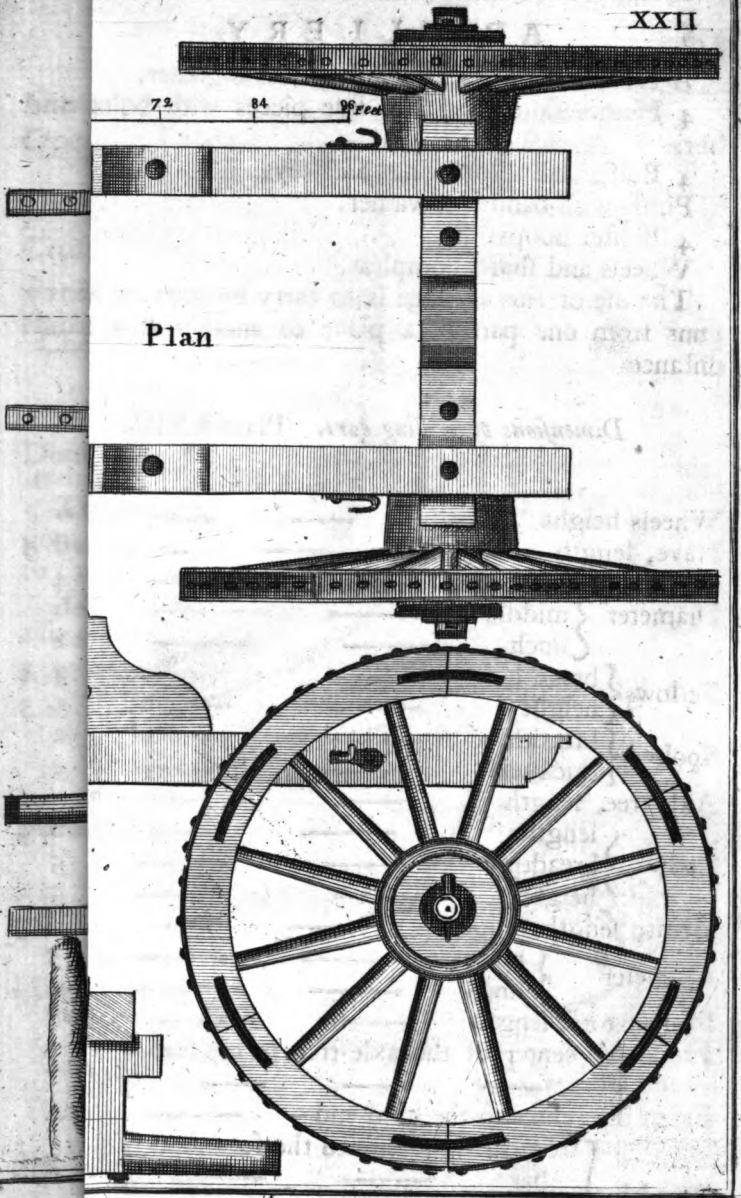
Wheels and ſhafts compleat.

The uſe of this carriage is to carry mortars or heavy guns from one part of a place to another at a ſmall diſtance.

Dimenſions of a ſling cart. Plate XXIII.

		Inches.
Wheels height		60
Nave, length		15. 5
Diameter	body	14
	middle	16
	linch	12
Fellows	breadth	3. 4
	height	5. 5
Spokes	breadth	2
	thickneſs	3
Axle-tree, length		77. 5
Body	length	40. 5
	breadth	5
	height	5. 5
Arms, length		18. 5
Diameter	body	5
	linch	4
Shafts, total length		168
From the center of the axle-tree to the fore end		144
From the center to the hind end		24
Breadth	from the hind end to the fore croſs bar	7
	middle	5
	fore end	3. 4

Opening



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		Inches.
Opening	axle-tree and fore croſs bar	23
	middle	30
	before	24
Height of the ſhafts		3.6
Croſs bars	breadth	4
	thickneſs	2
Cheeks to ſupport the roller	length below	28
	above	7
	height	9
	thickneſs	4
	interval	32
Diameter of the roller.		7

This cart ſerves for the ſame uſes as the former waggon, but chiefly to carry the guns from the water ſide to the proof place, and from thence back again.

The iron work of this cart is the ſame as before, as alſo of the wheels, axle-tree, and ſhafts.

Dimenſions of a truck carriage. Plate XXIV.

		Inches.
Fore axle-tree	body length	32
	breadth	5
	height	11
	arms length	6.5
	diameter	3
Hind axle-tree	body length	32
	breadth	6
	height	7.8
	arms length	6.5
	diameter	3
Side pieces	length	100
	breadth	10
	height	2.5
	interval	10
	to the fore axle-tree	15
	to the hind axle-tree	15

Fore

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		Inches.
Fore bolſter	length	32
	breadth	5
	height	6
Hind bolſter	length	32
	breadth	6
	height	8
Shafts	length	96
	height	3. 3
Opening	near the bolt	23
	middle	35
	before	24
Breadth	before	3
	middle	4
	at the bolt	3. 5
From the end to the ſtraight croſs bar		12
Fore guide	length	30
	breadth	21
	height	4
	interval	10
Trucks	diameter	25
	thickneſs	4

The croſs piece fixed upon the fore ends of the ſide pieces is 5 inches broad, 3 high before, and 1.5 behind.

The croſs piece behind the fore bolſter under the ſide pieces is ten inches broad, and 1.5 thick. The bolſters are let into the ſide pieces about half an inch. The iron work is ſo diſtinctly ſeen in the plan and elevation of this carriage, that it would be needleſs to mention it.

The uſe of this carriage is to carry timber and other burthens from one place to another.

Dimenſions of a travelling forge. Plate XXV.

	Inches.
Wheels, diameter	56
Nave, length	14

Diameter

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Pl. XXIII.

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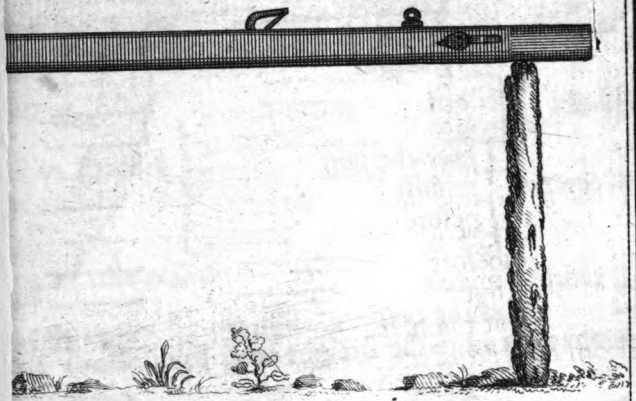

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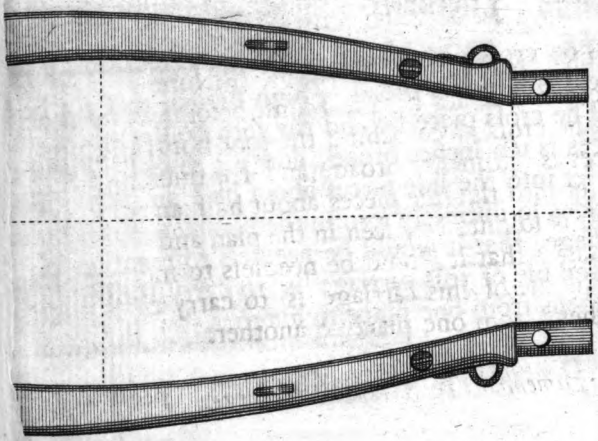

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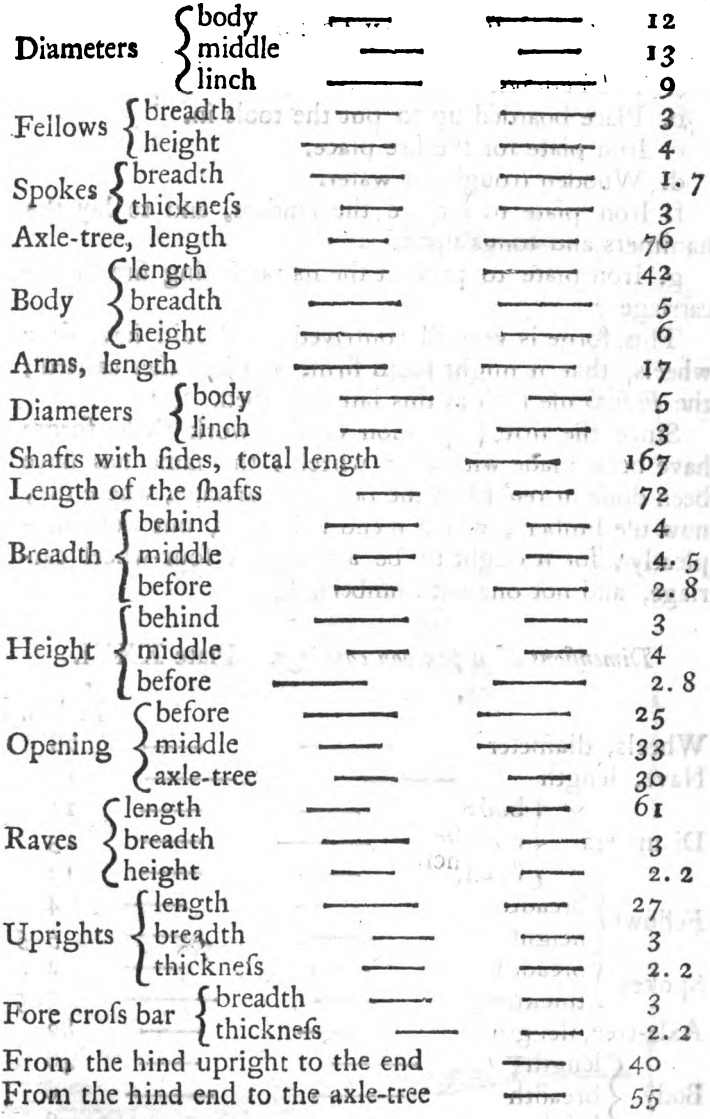

		Inches.
Diameters	body	12
	middle	13
	linch	9
Fellows	breadth	3
	height	4
Spokes	breadth	1.7
	thickneſs	3
Axle-tree, length		76
Body	length	42
	breadth	5
	height	6
Arms, length		17
Diameters	body	5
	linch	3
Shafts with ſides, total length		167
Length of the ſhafts		72
Breadth	behind	4
	middle	4.5
	before	2.8
Height	behind	3
	middle	4
	before	2.8
Opening	before	25
	middle	33
	axle-tree	30
Raves	length	61
	breadth	3
	height	2.2
Uprights	length	27
	breadth	3
	thickneſs	2.2
Fore croſs bar	breadth	3
	thickneſs	2.2
From the hind upright to the end		40
From the hind end to the axle-tree		55

EXPLANATION.

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Explanation.

a. The bellows.
b. Place boarded up to put the tools in.
c. Iron plate for the fire place.
d. Wooden trough for water.
f. Iron plate to receive the cinders, and to lay the hammers and tongs upon.
g. Iron plate to prevent the flame ſetting fire to the carriage.

This forge is very ill contrived; it ſhould have four wheels, that it might ſtand firm, and be eaſier carried; the *French* uſe ſuch as this laſt deſcribed.

Since the firſt impreſſion of this work theſe forges have been made with four wheels: the ſame has ſince been done in regard to the pontoon carriage, where they now uſe limbers, which mend it in part, but not compleatly; for it ought to be a compleat four-wheel carriage, and not one with limbers.

Dimenſions of a pontoon carriage. Plate XXVI.

		Inches.
Wheels, diameter		68
Nave, length		15
Diameters	body	14
	middle	15
	linch	12
Fellows	breadth	4
	height	5·5
Spokes	breadth	2
	thickneſs	3·5
Axle-tree, length		82
Body	length	46
	breadth	6
	height	8·5
Arms, length		18

Diameter

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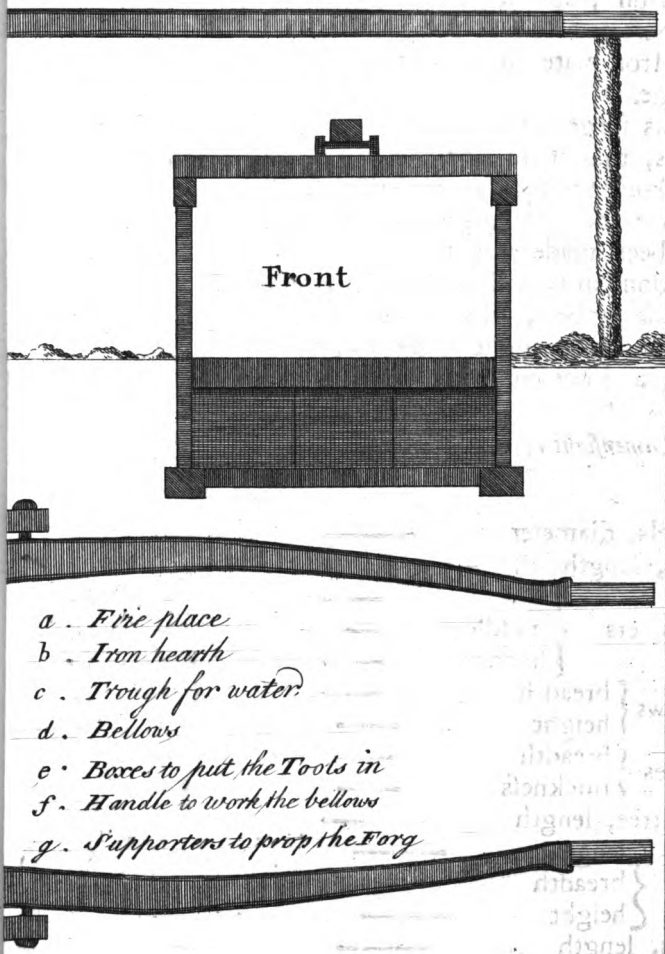
Travelling Forge



a. Fire place
b. Iron hearth
c. Trough for water
d. Bellows
e. Boxes to put the Tools in
f. Handle to work the bellows
g. Supporters to prop the Forg

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		Inches.
Diameter	body	6
	linch	3.5
Bolſter	length	54
	breadth	6
	height	18
Side pieces with ſhafts length		228
Breadth	axle-tree	5
	middle	4
	before	3.2
Height	behind the axle-tree	4.8
	before the axle-tree	6
	at 21.5 from it	5.2
	at the end	3.2
Opening	near the axle-tree	29
	at the fore croſs bar	28
	before	28
Fore croſs bar	breadth	4
	height	3.5
	length	60
Diſtance from the ſhafts end		108
Next croſs bar	breadth	4
	height	2.5
Diſtant from the firſt		24

The croſs bar next to the axle-tree is of the ſame dimenſions as the laſt, and 24 inches diſtant from the axle-tree.

The ſhafts ſlip through the axle-tree, and are pinned behind, ſo that they may be taken out when the carriage is to be put into the ſtorehouſe; for which reaſon they are made higher before, ſo as to afford a ſhoulder againſt the axle-tree.

Dimenſions of a pontoon.

	Feet.	Inch.
Total length of the pontoon	21	0
Length of the bottom	16	8

Width

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	Feet.	Inch.
Width above and below at the outside	4 :	10
Height of the sides	2 :	5
Width within { above	3 :	11
Width within { at the bottom	3 :	5
Depth within	2 :	1.5
Width of { three long bars underneath	0 :	5
Width of { the two side ones underneath	0 :	3.8
Breadth of the { upper ones	0 :	5.5
Breadth of the { cross bars	0 :	1.7
Distant from each other	0 :	9
Length of the timbers laid across	22 :	8
Breadth and height of ditto	0 :	4

There are four of these timbers for each pontoon, and as they lay across over two pontoons, there are 5 placed at the side of each other, the planks laid over them are an inch and a quarter thick, and 11. 5 feet long. There are likewise two long narrow boards laid on each side of the bridge over the ends of the cross ones, and fastened to them with wooden bolts, to keep the carriages from running off. The XXVIth plate shews the plan of the pontoon, one part of which is left open at the bottom, to shew the wooden work; both out and insides are covered with the strongest tin plates; the outside bottom is of the same breadth as the pontoon is at the top, the sides included, but the inside bottom is less broad, so that there is a hollow between the inside and outside, divided into apartments by the side pieces, in order that if a hole should be made in the outside by a shot or accident, the inside might not be filled, and the pontoon rendered less boyante.

The *French* cover the outside of their pontoons with strong copper plates, and use no lining within, which, in my opinion, is preferable to our method, because copper is much stronger than tin, and is not damaged by rust; and a stump of a tree or any thing that will make a hole in ours will not be able to hurt theirs; and since

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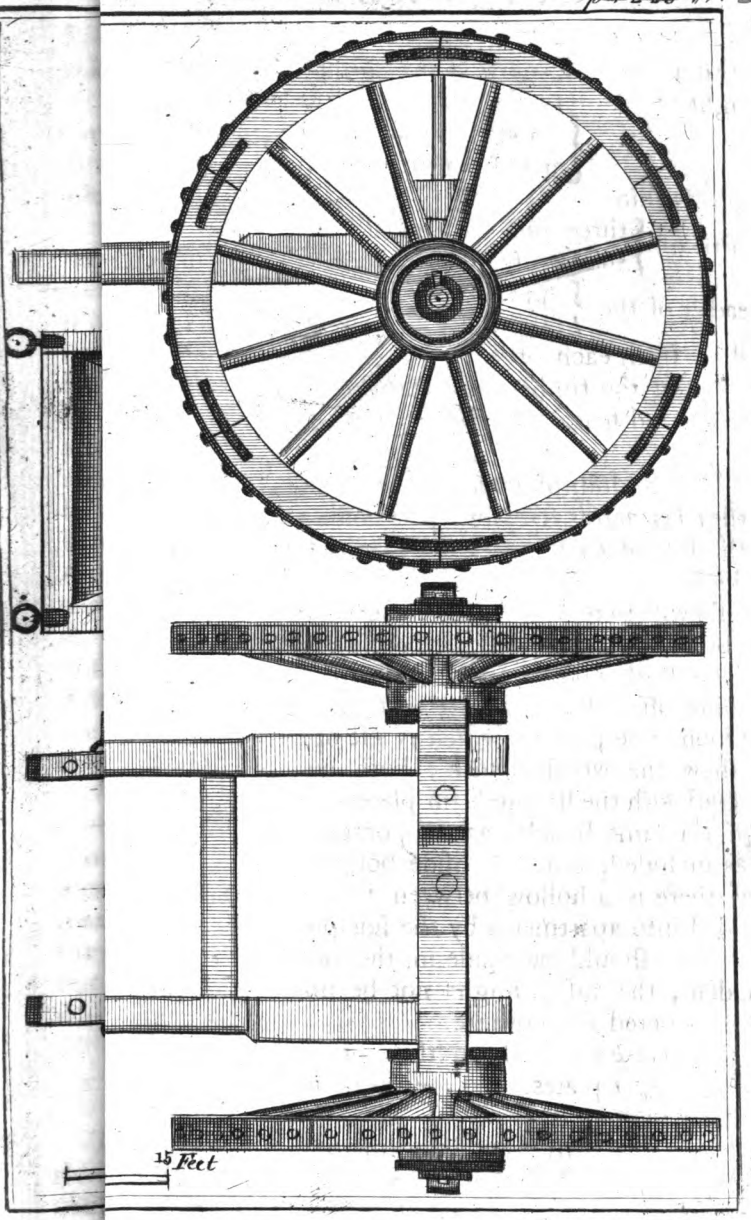

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ſince we have copper of our own, I cannot conceive the reaſon why we do not follow their method.

The pontoon carriage is as ill contrived as poſſible, for its length is greater than that of any waggon, and yet it is ſupported by two wheels only; they have ſince added a limber to it. The great ſtrefs that lies on the ſhaft horſe, would, one would think, be more than he can ſupport, eſpecially in going down hill; and I have been informed, that twenty men are ſcarcely ſufficient to aſſiſt him; and in going up hill the men are obliged to ſupport the carriage behind, for fear the weight ſhould overbalance that of the horſe. This being ſufficiently experienced in the laſt war, it is ſurpriſing that no artillery officer or artiſt have not contrived a more convenient carriage. The moſt obvious would be to have a limber to it, ſuch as the field carriages have; this the *French* have to theirs, but inſtead of making it with a high bolſter as uſual, I would make the wheels higher, and no bolſter at all, or only as high as the naves, ſo that the pontoon might lie as low as poſſible: by this means the carriage would go with more eaſe, and the ſhaft horſe draw as free as any of the others. To make uſe of two wheel carriages in travelling a great way, and through bad roads, is contrary to ſenſe and reaſon; becauſe the whole weight laying upon two wheels muſt needs make them ſink more in the ground than thoſe of a four wheel carriage, where but half the weight is ſupported by two: it is true that carts may be uſeful in a town at home, where they go upon pavement, and they are beſides cheaper; but that is no reaſon they ſhould be uſed abroad, for which, I dare ſay, they were not intended.

Of the gin. Plate XXVII.

The uſe of this machine is to mount cannons upon their carriages, or to diſmount them; alſo to heave mortars on or from their beds. It conſiſts of three round

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round poles of about 12 or 13 feet long, whoſe diameters at the lower end are about four inches, five juſt below the roller, beſides the cheeks that are added to them in that place, and about 3 or 3.5 inches above.

The roller is 7 ¼ inches in diameter, and ſix feet long; 20 inches are left ſquare at each end for the holes made in them to receive the hand-ſpikes, by which the roller is turned; the middle part is made round to wind the cable upon; the two poles, which ſupport the roller, are faſtened together by two iron bars, the one about 28 inches below the roller, and the other as much above it. Theſe bars are fixed with one end to one of the poles by means of a bolt, and with the other end to the other pole with a bolt and key, ſo as to be taken out, in order that when the gin is to be carried abroad, the poles may lay cloſe together upon the waggon; ſometimes wooden bars are uſed inſtead of theſe iron ones, which coſt leſs, and anſwer the purpoſe as well. There are two iron bands and two iron bolts to faſten each cheek to the poles, and likewiſe iron plates round the poles where the iron or wooden bars are fixed. The poles are hooped at each end, and thoſe above have ſtraps, through which the iron bolt paſſes. This bolt keeps the upper ends together, as likewiſe ſerves to ſupport the iron to which the windleſs is hooked: this windleſs contains two braſs pullies, about which the cable goes, which is fixed to the dolphins of the gun or mortar with another windleſs, containing two braſs pullies likewiſe.

The firſt figure ſhews the form of the gin, as likewiſe the dimenſions of the different parts, with all the iron work; therefore it would be needleſs to ſay any more of its conſtruction. It muſt be obſerved, that when it is to be uſed, it is laid flat on the ground, the lower end of the ſingle pole extends the contrary way, in order to faſten the upper windleſs after the cable has been turned round them; after this the upper end is raiſed

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raiſed gradually till the three poles ſtand nearly at equal diſtances.

The *French* gins differ from ours; *viz.* the two legs, which ſupport the roller, are faſtened together by three wooden bars, nearly at equal diſtances; the third leg is not fixed to the others, but enters into a notch or mortiſe above, ſo as not to ſlip when it is uſed; the upper windleſs is fixed to the two legs by means of an iron bolt, ſo that when they want to uſe the gin, a man gets up by means of the bars, and paſſes the end of the cable round the pullies. This I heard objected againſt, ſaying, that if the gun is mounted near an enemy, it would be dangerous; but as that gin is as eaſily raiſed as ours, they need not climb up, but when they can do it with ſafety.

Of Petards. Plate XXVII.

The *French* petards are made in the form of a fruſtum of a cone, with the vent in the leſſer baſe; in *England* they are made nearly in the ſame manner, only ſome are round towards the ſmalleſt baſe. The ſecond figure ſhews the ſection of one as they are made here; it is 8.5 inches within at the bottom; the diameter at the beginning of the round part is 6, and diſtant from the lower baſe 9 inches; the circular part is deſcribed from the point where the perpendicular to the ſides meets the middle line or axis; the thickneſs of metal is 1.6 inches; there is a brim at the bottom that projects the metal by two inches, and is one thick, in which are ſix holes of half an inch diameter, which ſerve for ſcrews to faſten the petard on a board in a firm manner; there is a cavity within at the bottom half an inch deep, and as much in height, to fix a board, to keep the charge in the petard before it is fixed to the board or plank. There are likewiſe two handles of about three inches from the flat ring, five inches long, ſeven tenths thick, and 1.8 from the outſide to the metal. Laſtly, a hole of an inch dia-

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meter is made either at the top or on the ſide, to ſcrew in an iron fuſe to fire the powder by, which fuſe is filled with a ſlow compoſition, in order that when it is lighted, the petardier may have time to retire out of danger.

Petards are made of various dimenſions, ſome larger, and others ſmaller than this; but it may be obſerved that they ſhould not be too heavy, otherwiſe it would be troubleſome to carry them to the gate or ſally port where they are to be fixed; and if they are too little, the effect would not be ſufficient, and therefore would be uſeleſs. In ſhort, the largeſt ſhould not weigh above 70 pounds when loaded and fixed to its plank, and the leaſt not leſs than 45 or 50.

It will be eaſy to make any other petard larger or leſs, in proportion to this, whoſe diameter of the baſe is given, by making all the other parts in the ſame proportion; thus, ſuppoſe the given diameter is 10 inches; to find the height between the two baſes, ſay, the diameter 8.5 is to the height 9, as the diameter 10 is to the height required, which will be 10.59 inches; and to find the thickneſs of metal, ſay, the diameter 8.5 is to the thickneſs of metal 1.6, as the diameter 10 is to the thickneſs required, which is 1.9 inches. In the ſame manner the dimenſions of any other part may be found.

The common way of loading the petard, and the beſt in my opinion, is, to fill it gradually with powder, and every two or three inches thick, to put a wooden mould into the petard, which being beat upon with a mallet, ſo as to preſs the powder as cloſe as poſſible, without bruiſing the grains, and when it is quite full, the board is put upon the powder, and over this a cloth with roſin, and bound round the brim with packthread to keep the charge and board together, till the petard is ſcrewed on the plank or board; then the part that exceeds the brim is cut off, and the other being preſſed by the brim, prevents any air coming to the powder.

The board to which the petard is fixed, is about two feet long, 18 or 20 inches broad, and 2.5 inches thick; it

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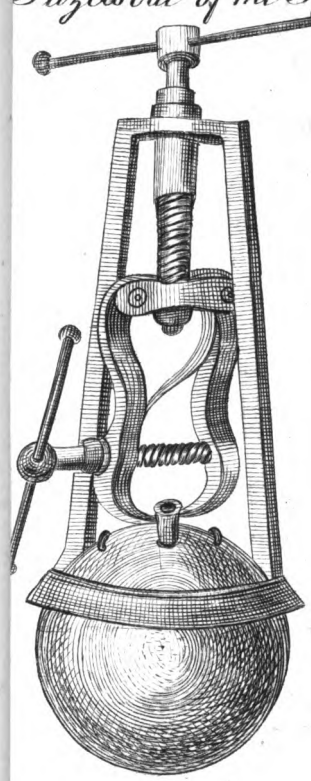
Box w

ngine for drawing
Fuzees out of the Shells



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it has two iron bands on the back, placed croſs-ways, and a hook to hang it up againſt the gate or door, by means of a ſcrew, when it is to be uſed.

Some moiſten the powder with ſpirits of wine, and dry it in the ſun to make it ſtronger, and then ſprinkle every layer of powder of two inches thick with mercury, upon which they lay powder again, and preſs it down, then ſprinkle it again with mercury, and continue ſo till the petard is filled; but in my opinion good powder alone, well preſſed down, is ſufficient to produce the deſired effect.

Petards have been much out of uſe ſince King *William*'s wars, when Mr. *Feuquier* forced open many ſmall towns in *Germany* by their means; but the danger that attends it, has deterred officers and partiſans from undertaking ſuch enterprizes. Nor do I find any other nation but the *French* have uſed them, and even they did not uſe them in the late wars.

PART VII.

The practice of artillery at home in time of peace, and its ſervice in time of war.

HAVING given in the former part of this work the conſtructions of the ſeveral pieces of artillery now in uſe, as likewiſe thoſe of their carriages, in the moſt conciſe and eaſy manner we could, we intend to give here a deſcription of what is practiſed at home in time of peace, in order to inſtruct the gentlemen cadets and private men in what they have to do upon the different occaſions that may happen in time of war; and then we ſhall deſcribe the different operations in the field and in a ſiege, taking the liberty of making obſervations wherever we think the preſent practice may be improved;

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not with any view of prescribing rules of my own making, but only to set before the judicious reader such things as may possibly be of service to those young gentlemen, who have not had an opportunity of learning them in real service; for we do not presume to offer these sentiments to those experienced officers of artillery, whose conduct and courage in the late war, so well known to every military gentleman, exempts them from all suspicion of being deficient in any part of their duty.

The practice at home.

In the spring, so soon as the weather permits, the exercise of the great guns begins, with an intention to shew the gentlemen cadets and private men the manner of laying, loading, and firing the guns, at various distances from the but or mark; and as the line of direction is not marked upon the guns, they have a small instrument called a *perpendicular*, to find the center line or two points, one at the breech, and the other at the muzzle, which are marked with chalk, and whereby the piece is directed to the target; this being done, a quadrant is introduced into the mouth, in order to give it a proper elevation, which at first is guessed at, according to the distance the target is from the piece. When the piece has been fired, it is sponged, to clear it from any dust or sparks of fire that might remain in it, and loaded: then the center line is found, as before; and if the shot went too high or too low, the elevation is altered accordingly. This way of firing continues morning and evening for a month or six weeks, more or less, according as there are a greater or less number of recruits. In the mean time, others are shewn the motion of quick firing with field pieces.

REMARKS.

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REMARKS.

No gun is ever turned ſo true, that the outſide correſponds exactly with the inſide; becauſe, if the bluntneſs of the tools and the heavineſs of the work is rightly conſidered, it will be found morally impoſſible that it ſhould; and the manner of laying pieces, or finding the line of direction, by an inſtrument applied on the outſide, can be but very dubious and uncertain; it alſo miſguides the gunner; for when the *perpendicular* is not always placed exactly in the ſame manner, it will give different lines of directions, whereby he is not able to judge when the ſhot does not hit the mark, whether it is owing to his want of ſkill, or to the falſe direction; and conſequently is never certain whether he underſtands his buſineſs or not. I ſhould imagine, that if the line of direction was marked, as was formerly the cuſtom, with a ſlit or cavity at the breech, and a button at the muzzle, it would be much better; for though this line ſhould not exactly anſwer the direction of the bore, yet when the gunner has once found out its defect, he will eaſily know how to rectify it: this I have ſeen in a piece formerly in *France*, which, when directed at the mark, went a great deal to the left; but the gunners, after the firſt ſhot, hit the mark with it as well as with any other. It is true, that an objection is made againſt this fixed line; for it is ſaid that the platforms are never laid ſo exactly level, but that one wheel will always be higher than the other; and in that caſe the line of direction muſt be falſe. But as I never have ſeen a platform made without a maſon's level, and this is, as far as I know, an univerſal cuſtom, I cannot ſee any foundation for this objection; but let us ſuppoſe that one wheel was a trifle higher than the other, this would cauſe very little error in the direction, which however the gunner would rectify the very next ſhot: but though the platform ſhould be level, it is ſaid the wheels do not always

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ſtand exactly in the ſame place, whereby the line of direction is changed every time; this the gunners always take care of, by marking the ſituation of the wheels, and the hind part of the carriage with chalk on the platform. Therefore, ſince the laying a piece with the line of direction upon it, is more expeditious, and at the ſame time more certain, it appears to be preferable to the common practice.

As the quadrant is introduced into the mouth of the piece, merely to know its elevation, and when the ſhot goes either higher or lower than the mark, it is lowered or raiſed by gueſs only, without having any rule to go by, the uſe of that inſtrument can be of no advantage in practice; on the contrary, it prevents the gunner from learning to judge by the eye, what elevation the piece ſhould have according to its diſtance from the object, which he ſhould be able to do when he comes to real action; for which reaſon it ought to be rejected, as well as the *perpendicular*, whether a line of direction is marked on the piece or not.

As the intention of the exerciſe in time of peace, is to render the young artilleriſt ſkilful in all the different branches of his buſineſs, I think, that if faſcine batteries were frequently raiſed, and platforms laid, that they may know how to do it in time of war, and at the ſame time accuſtom the men to fire through embraſures, it would conduce very much to their perfection: for the manner the exerciſe is carried on at preſent upon a ſtone platform, without any declivity, and without breaſt-work, can give no true idea of the firing in a ſiege; the moſt it can do is to repreſent a faint notion of firing in a battle, where no battery or platform is made, except in ſome caſes where a poſt is to be defended. I know an excuſe is made, that it is the duty of the engineers and not that of the artillery officers to make the batteries, and they have hitherto made them accordingly, as far as I know: yet as this cuſtom is grounded upon very erroneous principles, as we ſhall prove, it ought to be abolished.

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abolished. For how seldom does it happen that an engineer in this country has an opportunity to make a battery? and when he has, how shall he know whether the embrasures are rightly made, or what declivity the platform should have, except he is well acquainted with the artillery, or is instructed by the officers of artillery? It may be said, he ought to be acquainted with what has been done by former engineers; but as the length and weight of pieces is changed almost every day, and of course the making the embrasures and platforms must change likewise, it is impossible he should know how to make a battery in a proper manner, unless he was ordered to make experiments every time that pieces are changed, which is never done. Whereas, on the contrary, the officers of artillery are on the spot, and, by firing these guns, have all the opportunity they can wish to determine these things; and to shew the necessity of it, we shall give an instance which makes it evident: formerly, when a 24 pounder weighed from 51 to 52 hundreds, and its length was 10 feet, the platforms were then made 18 feet long, and 9 inches higher behind than before; and now we make 24 pounders, that weigh but 17 hundreds, and whose lengths are 5.5 feet; and as it may happen that these pieces are used upon a battery, how should an engineer be able to raise one properly? and if he makes it as customary, the guns will run off their platforms every time, by which the service will be retarded, and who is to be blamed? not the engineer, as I conceive, since he had no opportunity to try these pieces before-hand. Again, the diameter of the wheels for heavy gun carriages is 58 inches, and that of the light pieces 50 only; so that the height of the embrasures must be made less for the latter than for the former. The distance of the battery from the object depends on the range of the pieces; and as the light carry not so far as the heavy, by reason that their charges are less, a battery for the light pieces must be nearer the object, than that for the heavy. And since

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no one can be a better judge than the artillery officers, who daily practiſe them, they are therefore the propereſt to direct the making of batteries.

As the word *point blank* is often miſunderſtood, we ſhall endeavour to define it here according to the general and proper acceptation; which is, ſuppoſe a piece ſtood upon a level plain, and laid level, then the diſtance between the piece and the point where the ſhot touches the ground firſt, is called the *point blank range* of that piece; but as the ſame piece ranges more or leſs, according to a greater or leſs charge, the *point blank range* is to be underſtood to be that, when the piece is loaded with that charge, which is uſed commonly in action. It is therefore neceſſary that the ranges of all pieces ſhould be known, ſince the gunner judges from thence what elevation he is to give to his pieces, when he is either farther from or nearer to the object to be fired at, and which he can do pretty nearly by ſight, eſpecially if he has practiſed it often.

Ricochet firing is likewiſe neceſſary to be practiſed, that is, the pieces are elevated from three to ſix degrees, and loaded with a ſmall charge, in order that the ball may be bound and roll along the inſide of the parapet; for which reaſon a front of a polygon ſhould be made, to ſhew the gunners clearly the object of theſe batteries, and to try and find the charges for various diſtances; but as no work of this kind has hitherto been made (though according to the inſtructions of the academy there ſhould) piquets or ſtakes might be placed at proper diſtances, to repreſent the traverſes or the angles of the front of the polygon, which will anſwer the purpoſe nearly as well as if there were real works. As this method of firing ſaves a great deal of powder, and is more dangerous than the uſual way, as will be ſhewn hereafter, it ought by all means to be practiſed in time of peace.

Mortar.

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Mortar practice.

After the gun exercise is over, that of mortar begins, and sometimes they are carried on both together; the usual manner is thus: a line of 12 or 1500 yards is traced in an open spot of ground, from the place where the mortars stand, and a flag fixed on the end; this being done, the ground where the mortars are to be placed is prepared and levelled with some sand, so as they may stand at an elevation of 45 degrees; then they are loaded with a small quantity of powder at first, but increased afterwards, by an ounce every time, till it is loaded with a full charge: the times of the flights of the shells are observed, to determine the length of the fuses.

The intention of this practice is, when a mortar battery is raised in a siege, to know what quantity of powder is required to throw the shells into the works at a given distance, and to cut the fuses of a just length, that the shell may burst as soon as it touches the ground. This is certainly a very good method, with regard to its intention; but in a siege shells are not or never should be thrown with an angle of 45 degrees, but in one single case only, which scarcely ever happens, that is, when the battery is so far off that they cannot otherwise reach the works. For when shells are thrown from the trenches into the works of a fortification, or from the town into the trenches, they should have as little elevation as possible, in order to roll along, and not bury themselves, whereby the damage they do, and the terror they cause to the troops, is much greater than if they sink into the ground. On the contrary, when shells are thrown upon magazines, or any other buildings, with an intention to destroy them, the mortars should be elevated as high as possible, that the shells may acquire a greater force in their fall.

It

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It is ſaid that howitzes are made to throw ſhells with a ſmall angle of elevation, and therefore it is not neceſſary to uſe mortars for that purpoſe, and that an angle of 45 degrees is ſufficient in a bombardment; which may likewiſe be done with leſs powder than at any other elevation.

Granting this, I ſhould be glad to know the uſe of mortars, at leaſt of the ſmall; ſince no leſs than 13 inch are or ought to be uſed in throwing ſhells upon magazines, and even thoſe are not always ſufficient to break through the arches of powder magazines; therefore it would be needleſs to carry any ſmaller to the field. But the true reaſon is, our mortars are immoveably fixed to their beds, and the cuſtom has prevailed for ſome years, to laſh them ſtrongly with ropes to their beds, which could not be done if they were moveable, and the belief that without this laſhing they would kick up before, and fall backwards when fired. But to convince the reader of the inſufficiency of this reaſon, he muſt know that the *French* never laſh their mortars, though they are much ſhorter and lighter than ours, and often fire them with an angle of 75 degrees, without their ever falling back, as we abſurdly imagine. This is demonſtrable without having recourſe to any experiments; for we have ſhewn that confined powder acts every where alike when fired, but being reſiſted in pieces of artillery on the ſides by the ſtrength of the metal, the ſhot is driven forwards, and acts likewiſe on the oppoſite part ſo as to make the piece recoil. Now as action and re-action are always equal and oppoſite, whilſt the action on the upper part of the chamber endeavours to raiſe the mortar, that on the under ſide oppoſite to the other acts with the ſame force downwards; and therefore theſe two forces being equal, and in oppoſite directions, they deſtroy each other. Hence, there is not the leaſt occaſion to laſh the mortars to their beds, nor fix them immoveable, as hitherto has been the cuſtom.

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N. B. What we have ſaid here relates to land mortars only; for thoſe on board bomb-veſſels are ſo heavy, and the motion of the ſhip ſo variable, that it would be needleſs to attempt any other method than what is uſed.

In firing mortars no wadding is uſed here upon the powder, in order that the blaſt of the powder in the chamber may light the fuſe of the ſhell by means of a quick match; on the contrary, the *French* put a wad upon the powder, and fill the reſt of the chamber with earth; and when the mortar is fired, one gunner fires the fuſe, while another fires the powder in the chamber. But as the fuſe might by chance take fire before the powder, the ſhell might burſt in the mortar, ſpoil it, and endanger the lives of the men, and as the earth can make but very little reſiſtance, the powder acts nearly with the ſame force as if there was none; therefore this method is very defective, and much inferior to ours.

Inſtead of loading mortars with looſe powder, as is the cuſtom, I would chuſe to uſe cartridges as well as in guns, for the following reaſons; becauſe when the powder lies looſe, its ſurface ſpreads near horizontally, ſo that the lower part lies nearer the ſhell than the upper, which makes its effect much leſs than it would be were it confined; neither can the chamber be filled with as much powder as it can hold, for which reaſon they are always made larger than they ſhould be, whereby the effect is never ſo great as it would be otherwiſe: thus in our thirteen inch mortars the chamber holds nine pounds of powder, whereas it is well known that ſix pounds is the moſt that is wanted; and ſince looſe powder never acts with that force it does when confined, it is evident, that the firing mortars with looſe powder is not ſo advantageous as when they are fired with cartridges. Another advantage this manner has over the other is, that when the chamber is not filled, the cartridge may be left cloſe to the ſhell, and the empty ſpace at

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at the bottom of the chamber, whereby the powder acts with more violence than if the powder was at the bottom of the chamber, and the empty ſpace near the ſhell; this colonel *Deſaguliers* and myſelf tried many times with half the charge, and the range was always nearly double in the firſt caſe than in the ſecond. When the powder is looſe in the chamber, if a piece of writing paper be put over it to keep it up, it will make a greater range than otherwiſe: all this confirms, that with leſs powder a greater effect may be produced, than with a greater quantity, which ought not to be neglected.

We have ſhewn the inconveniency of fixing mortars to their beds ſo as not to be moved, becauſe they never will produce the effect that might be expected; we ſhall add another reaſon, which is, that when the charge is the ſame, and the elevation varies, the rules of projectiles may be uſed, which, though deduced from the theory of bodies moving in a non-reſiſting medium, and the reſiſtance of air is conſiderable in ſwift motion, yet they will give the ranges very near under 1200 yards; for which reaſon we ſhall ſet them down here, leaving it to practitioners to try them, or let them alone, as they think proper.

Practical rules for horizontal ranges.

I. *The range of a body projected with an angle of* 15 *degrees, is half the range of that body, if projected with the ſame force with an angle of* 45 *degrees.*

II. *The range of a body projected with an angle of* 45 *degrees, is equal to the ſquare of the time of its flight, expreſſed in ſeconds multiplied by* 16.1 *feet.*

III. *If a body be projected with the ſame force, but with different angles of elevations, the horizontal ranges are as the ſines of angles double thoſe of the elevations reſpectively.*

IV. *The*

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IV. *The times of the flights of the same body, projected with the same force, with different degrees of elevations, are to each other as the sines of the angles of elevations.*

These rules are demonstrated in my Elements of Mathematics, Book the fourth, Section the third.

Example I.

Let a body projected with an angle of 45 degrees of elevation be 12 seconds in its flight, what is the horizontal range?

The square of 12 is 144, which multiplied by 16.1, gives 2318.4 feet, or 772.8 yards, by rule the second, for the range required.

Example II.

If the range of a body projected with an angle of 25 degrees be 200 yards, what will be the range if the body is projected with the same force under an angle of 30 degrees?

The sine of 50 degrees, double of 25, is 76604, and the sine of 60, double of 30, is 86602; therefore 76604 : 86602 : : 200 : 226, equal to the range required by the third rule.

Example III.

If the range of a body projected with an angle of 20 degrees be 200 yards, what must the angle of elevation be to project the body with the same force at a distance of 300 yards?

The sine of 40 degrees, double of 20, is 64278; whence 200 : 300 : : 64278 : 96417, equal to the sine of the angle double the required one: this sine answers

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to an angle of 74 degrees 37 minutes, half of which is 37 degrees 18.5 minutes, for the angle ſought.

Example IV.

The horizontal range of a body projected with an angle of 45 degrees being 1000 yards, to find the time of its flight?

Then ſay, as 16.1 feet is to the given diſtance 3000 in feet, ſo is unity to the ſquare of the time required, which is 186, whoſe ſquare root 13.6 ſeconds will be the time required.

Example V.

If the time of flight of a body projected with an angle of 45 degrees is 20 ſeconds, what will be the time of the ſame body projected with the ſame force with an angle of 35 degrees?

As the ſine of 45 degrees is 70710, that of 35 degrees 57357; whence 70710 : 57357 :: 20 : 16, equal to the time required.

This laſt example ſhews how to compute the time of the flight of a ſhell when the range can be meaſured, and from thence the length of the fuſes; as likewiſe at ſea, where the diſtance is known from the mortar to the object, the time being computed when a ſhell is thrown, it may be known whether it fell ſhort, or goes beyond the object, according as the time obſerved of the flight is leſs or greater than the time computed.

Theſe are nearly all the different exerciſes of the artillery in time of peace, except that the men are ſhewn ſometimes how to take the guns off their carriages, and to put them on; whence the reader may ſee, that the artillery art is chiefly reduced to fire guns and mortars; but as theſe exerciſes are ſoon over, and a great deal of time

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time is ſpent in doing very little, which generally makes the private men get idling about, ſpend their money, and do miſchief for want of other employment, I propoſe the following ſcheme to employ them for the good of the public, without any hardſhip to them.

When all the field exerciſes and that of ſmall arms are over, and nothing to be done, a detachment of private men, commanded by young officers, conſiſting of about a ſixth part of the garriſon, ſhould be ordered to attend the laboratory, to make and prepare all kind of military ſtores that are neceſſary, during three hours in the morning, and three in the afternoon; at other times they ſhould be employed to make fireworks for the uſe of artillery, and for rejoicings; this would be no hardſhip upon the ſoldiers to be employed once a week for ſix hours, the officers would have leſs trouble to keep them clean and ſober; they would likewiſe know how to prepare thoſe ſtores when they are wanted to be ſent abroad, where there is no laboratory, and yet neceſſary to be had. Laſtly, great expences would be ſaved to the public, without any hardſhip or detriment to any body.

This would alſo be a means to inſtruct the young officers in that branch of their buſineſs, of which they ſhould not be ignorant: for how often does it happen, when a detachment is ſent to the *Eaſt* or *Weſt-Indies*, where having powder, ſhells, and ſhot, it is neceſſary to make grape ſhot, fill the ſhells, and drive the fuſes; or after having gained a victory, to make fireworks for rejoicing; now if an officer does not know to order how theſe things are to be done, what a figure muſt he make before a commander in chief, who requires it of him, and expects he ſhould be able to do it!

I think it alſo neceſſary that an artillery officer ſhould know the names of every thing neceſſary for a field equipage, eſpecially of all the parts of a gun, a mortar, and their carriages; for if any accidents happen in a ſiege, how can he ſend word to the workmen, who are generally

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generally in or near the park of artillery, of what is wanting? for they, not knowing what is broke, muſt come perhaps a mile to ſee it, and go back again to fetch it; in the mean time the piece cannot be fired, whereby the ſervice is retarded.

It appears alſo to be neceſſary upon many occaſions, that the officers ſhould be acquainted with the principal conſtructions of gun and mortar carriages; for it may happen, that when they are ſent upon an expedition to the *Eaſt* or *Weſt-Indies*, where either new carriages may be wanted, or old repaired, they may always find wood and iron; as likewiſe ſmiths and carpenters in the country, but who not being acquainted with this kind of work, if he knows how to direct them, it will be both an advantage to him as well as to the ſervice: it may be ſaid, that there are always workmen ſent with thoſe detachments by the board of ordnance, whoſe duty it is to do thoſe things; but if thoſe artificers ſhould die, which may happen, what muſt be done then? if the officer does not know how to direct others, the conſequence will be, that the ſervice muſt be retarded, and who will be blamed?

It is likewiſe very material, that an officer ſhould know the quantities of ſtores and their kinds that are required upon any expedition. It is true that this detail is commonly made out at the Tower; but if by miſtake any material article ſhould be omitted, when he comes to an action and wants it, the commanding officer would blame him, and not thoſe that ſent them.

The ſervice of ARTILLERY *in a land engagement.*

The pieces are generally placed upon ſome riſing ground before, and at the ſides of, the firſt line, where the enemy is ſuppoſed to make the greateſt effort, or in ſome village, garden, or near ſome hollow way through which he can march; and as they are to advance or retreat, according as the army moves and the enemy approaches,

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approaches, there is no time for raiſing batteries, except a ſpot of ground is taken poſſeſſion of the night before, which is advantageous for covering either a wing or the center, and neceſſarily to be kept and defended; the heavieſt pieces ſhould be placed there, and the others in the moſt advantageous manner the ground will admit of: every time they are fired the men advance them to the ſame place again; ſo that when the guns are once pointed right, they continue ſo all the time they remain in the ſame place. Our preſent light pieces are wonderfully well adapted for this ſervice, the men being able to move them as they pleaſe with very little trouble, and the ſcrews uſed to keep them at the ſame elevation are much more convenient than the coins which were uſed before, becauſe they fly off every time the pieces are fired.

At firſt the guns are fired with balls, but when the enemy comes near, they are then loaded with grape ſhot. In this caſe the charge ſhould not be ſo much as before, becauſe it has been found by experience, that when the charge is great, the ſhots ſpread too much, by ſtriking againſt each other, whereby many of them do no execution, which ſhould be avoided if poſſible. In my opinion a ſixth part of the weight of the ſhot will be ſufficient upon this occaſion. But when pieces are loaded with balls, one fourth, or perhaps one fifth will be the proper charge, ſince no more was uſed in our light pieces during the laſt war.

It has been obſerved by ſeveral artillery officers, that howitzes might be uſed in an engagement to very great advantage, if they were placed in the flanks, ſo as to fire obliquely upon the enemy's line, or amongſt their horſe, when loaded with ſmall charges, that the ſhells may roll and bound along, whereby a great diſorder would enſue among them; which being perceived, if they are briſkly charged, might be the means of gaining the day. For it muſt be obſerved, that cannon ſhot paſs ſo ſwift through the ranks, that men are killed

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without ſeeing the danger, which the reſt look upon as an accident attending their buſineſs; but when they perceive the ſhells rolling along with their fuſes burning, and expecting them to burſt every moment, the braveſt amongſt them will hardly have the courage to wait for their coming near him.

When pieces are fired with cartridges, the bottoms will remain in them whatever care can be taken; they muſt therefore be drawn from time to time, or elſe they will accumulate ſo that the tube cannot reach the powder. The ſhorteſt way of doing this, is to fix a worm at the head of the ſponge with a good ſpring, ſo as when it is preſſed upon, it may ſponge the bottom of the piece, and draw out the remaining bottom at the ſame time; for all other methods propoſed by ſome artiſts are inſufficient. Another method I think might likewiſe do, is to pierce the vent from behind the breech, in the manner the *Saxon* guns were, whereby the tube cannot miſs to reach the powder, provided it is of a ſufficient length: beſides, the cartridge being pierced in the bottom, ſome grains of powder may probably fall between the cartridge and the end of the bore, and ſo blow out the bottom with the reſt.

It is to be obſerved, that the powder carts ſhould be near the batteries, not only to ſupply them with powder, but likewiſe the troops near them, when that which they receive before the engagement is all ſpent; becauſe batteries are objects or marks of ſuch a nature as to be known at a great diſtance, whereas, when the powder is placed any where elſe, the troops do not know where to find it if they are in want. But at preſent every battalion has two field pieces to attend them, which I ſuppoſe have powder carts along with them, that contain a ſufficient quantity to ſupply the battalions.

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The ſervice of ARTILLERY *in an attack.*

The firſt batteries erected in an attack are generally placed about a hundred yards before the firſt parallel upon a riſing ground, if there is any that lies conveniently, and as they commonly are made for ricochet firing, muſt be at right angles to the faces produced of the works in the front attacked, and there being eight faces in the front, when there are ravelins and a covert-way, ſo there muſt be eight batteries, each of four guns at leaſt, beſides ſome mortars placed in the ſame batteries.

When ricochet firing is uſed, the pieces are elevated from three to ſix degrees, and no more; becauſe if the elevation is greater, the ſhot will only drop into the work, without bounding from one place to another; they are to be loaded with a ſmall charge, and directed in ſuch a manner as juſt to go over the parapet.

Mr. *Vauban* ſays, that half a pound of powder is ſufficient for a 12 pounder in moſt caſes; which is one twenty-fourth part of the ball's weight: therefore wherever this firing can be practiſed, it ſhould be done, ſince it ſaves much powder, and the pieces will not be heated let them be fired ever ſo much. The ſame batteries will likewiſe ſerve to diſmount the beſieged guns placed in the faces oppoſite to them; but in that caſe the charge muſt be one fourth, or one third of the ſhot's weight. The chief engineer and the commander of artillery conſult together how to place theſe batteries, and when the places are fixed upon, the pioneers are ſet to work, under the command of an artillery officer in the *French* ſervice, where they have a particular number called commiſſaries, who are not attached to the regiment of artillery, and when the ground is thrown up, the gunners make the inſide facings with faſcines themſelves, as likewiſe the embraſures, and lay the platforms; for nobody can be a better judge how to do this work than

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they, and therefore they ought to practiſe it in time of peace, as we have obſerved before.

The next batteries to be raiſed are thoſe for making breaches, and to deſtroy the flanks: the firſt are placed upon the glacis, within 18 or 20 feet of the covert-way, directly oppoſite to the faces in which they are to make breaches, and the others alſo upon the glacis at the ſame diſtance from the covert-way, oppoſite to the flanks. This diſtance is left for the thickneſs of the breaſt-work or parapet.

It has been cuſtomary to charge the pieces with half the weight of the ſhot; but experience has ſhewn, that one third or leſs is ſufficient; for provided that the ſhot juſt enters the wall, the effect will be greater than when it penetrates a great way. The manner of making a breach is to fire at firſt as low as poſſible, and to direct the pieces ſo as to hit in an horizontal line near each other; if they are fired together, and not one after another, the ſhock will be the greater.

The reaſon for battering ſo low is, that if the wall is cut low in an horizontal line, the part above falls down all at once; whereas if the wall above is beat down at firſt, the rubbiſh covers the lower part in ſuch a manner, as not to be deſtroyed afterwards, and without which the breach becomes impracticable. When the wall is once beat down, it will be advantageous to fire ſhells into the earth, for each ſhell will produce the ſame effect as a little mine; whereas the ſhot will only make a hole of its own bigneſs, without any great effect. It has been found that the vents of battering pieces have been ſo much ſpoiled in a ſiege, as to render the guns unſerviceable: this may be prevented by firing with tubes, as in quick firing it has been found by experience that they preſerve the vent, for we fired a ſix pounder 300 rounds in 3 hours and 27 minutes, without widening the vent in the leaſt; conſequently this manner of firing ſaves great expence, ſince the ſame guns may ſerve in many

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many ſieges, without having them recaſt, as was the caſe heretofore.

The ancients made uſe of much larger calibers for battering pieces than we do; they knew very well that the breach is ſooner made with them; but they imagined that the greater the force was, the quicker the work was done; for which reaſon they loaded their guns with as much powder as the ſhot weighed; and as the ſtrength of the guns was made in proportion to the effort they ſuſtained, they became ſo very heavy, as hardly to be managed; for which reaſon none but 24 pounders are uſed at preſent, whoſe ſtrength is made ſo as to bear a charge of two thirds of the ſhot's weight; and though experience has ſhewn that one third was ſufficient, yet their weight has not been diminiſhed.

This was the reaſon that induced us to make the battering pieces lighter, for we made the thickneſs of metal but three quarters of the ſhot's diameter at the vent, inſtead of a whole diameter, as in the preſent. And as the ſtrength of a piece is in proportion to the thickneſs of metal, that of ours will be to that of the preſent pieces, as 3 to 4; and the forces being nearly as the quantities of powder, ours will be acted upon but with half the force of the old, and conſequently their ſtrength is more than ſufficient upon all occaſions.

Now as our new 42 pounder weighs 47 : 1 : 0, and is 10 feet long, and the old 24 pounder weighs about 51 : 0 : 0, and is only 9½ feet long, we conceive that our new piece is much preferable for making a breach to the old 24 pounder. For it enters farther into the embraſures by ſix inches, and of conſequence does not deſtroy them ſo ſoon; it requires no more men to manage it, and no more horſes to draw it; and as it will ſooner make a breach, there can be no compariſon made between their uſefulneſs. As to the charge, I would never uſe more than ten pounds of powder, for the forces of ſhots are in proportion to their weight multiplied by the weight of the powder; whence a 42 pounder

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der loaded with ten pounds of powder will produce a force, which is to a 24 pounder loaded with the ſame charge, as 42 to 24, or as 7 to 4. This is the particular excellency of large calibers, that they produce a greater force with leſs powder in proportion; and conſequently they are much preferable in moſt caſes. And they have another advantage, which is, when you fire at a diſtance with a proportionable quantity of powder, the reſiſtance of the air is reciprocally proportional to the diameters of the ſhots nearly; thus the diameter of a nine pound ſhot is 4 inches, that of a 49 pounder 7 nearly; and therefore the reſiſtance of the 9 pounds is to the reſiſtance of the 49 pounds, as 7 is to 4 nearly. Whence it appears, that the firſt will meet with a reſiſtance near double that of the ſecond.

Conſtruction of batteries.

To make a battery before the face of a vigilant enemy ſtrong and durable, and to uſe no more materials and workmen than are neceſſary, is perhaps the moſt important work in a ſiege: though the enemy do not know their ſituations, yet may gueſs where they ſhould be, and prepares his fire accordingly; and ſo ſoon as he hears the leaſt noiſe of workmen, will do all he can to annoy them both by his fire and ſallies; being ſenſible that when they are once made they will deſtroy all his defences, and diſmount his guns; and when that is effected, the approaches may be carried on without any other obſtacle than the fire of ſmall arms, againſt which the workmen may eaſily cover themſelves.

To proceed with order, the quality and quantity of the materials, as well as the number of workmen and their tools, muſt be determined as exactly as the nature of the ſubject will admit. From the known dimenſions of a battery, the quantity of the materials may be determined and their kind from their ſituation. For the parapet or breaſt-work is 18 or 20 feet thick, and 7.5

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or 8 feet high; each gun takes up 18 feet parapet, and each end about 10: the embraſures are 3 feet from the ground, 2 feet wide within, and 15 or 16 without; ſo that the merlons or part between the embraſures are 16 feet long on the inſide, and 4.5 or 5 feet high.

The dimenſions of the faſcines are various, but the following are in my opinion the moſt convenient in many reſpects; their diameters ſhould be 10 inches or circumference 31.5, and their length 10.8 and 6 feet: becauſe one of 10 feet and one of 8 make the thickneſs of the parapet; one of 10 and one of 6 the merlons; one of 10 the ends; and one of 10 and 8 the inſide of the embraſures: laſtly, 9 layers make up the height of the parapet. Another advantage of the above lengths is, that the ends of one layer will not be over thoſe of the next above it, and they are made and carried with more eaſe than thoſe that are longer, ſuch as the *French* generally uſe.

Hence a battery of two pieces will be 40 feet long, and requires two faſcines of 10 feet, one of 8, and two of 6 for each layer from the ground to the embraſures, and four layers 8 of 10, 4 of 8, and 8 of 6 feet, which are required for that height; becauſe four layers make 40 inches in height, and the under one being ſunk about 4 inches into the ground, there remains 3 feet.

The diſtance between the two embraſures being 16 feet, requires one of 10 feet, and one of 6, and each end one of 10, that is, three of 10, and one of 6 for each layer; and if we take 6 layers, 18 of 10, and 6 of 6, which makes the parapet 8 feet high; though 6 layers will be ſufficient on moſt occaſions, yet it is proper to have ſome ſpare faſcines.

As the embraſures are likewiſe to be ſecured with faſcines, each layer requires one of 10 feet, and one of 8; ſo that the ſix layers require 6 of 10, and 6 of 8 feet; and as two embraſures require four times that number, that is, 24 of 10, and 24 of 8; to which muſt

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be added one to lay over each embraſure of 6 feet long, to cover the gunner againſt the plunging muſket ſhot; which two added makes 24 of 10, 24 of 8, and 2 of 6, for the number of faſcines required for the embraſures. The ends of the parapet are likewiſe ſupported with faſcines, one of 10 feet, and one of 8: and the ten layers 10 of 10, and 10 of 8; and both ends 20 of 10, and 20 of 8 feet long.

So that a battery of two pieces requires 70 of 10, 48 of 8, and 16 of 6 in all. When a battery is enfiladed by ſome of the outworks, they muſt have flanks from 10 to 12 feet thick, and 18 long, which requires 10 faſcines of 10 feet, and 10 of 8 each flank; and when the ſoil is ſandy, it is ſcarcely poſſible to keep up the earth on the outſide without faſcines, at leaſt from the berm to the embraſures; for which it requires 8 of 10, 4 of 8, and 8 of 6, in any battery of two pieces.

Beſides theſe battery faſcines, others of a ſmaller ſize are required, which I ſhall call *bavins*, to lay along the rope which traces the plan of the battery, and confines the earth till the other faſcines are laid and picketed; as likewiſe to cover the powder magazines: their diameter may be 5 inches only, and length 6 feet. Theſe magazines muſt hold as much powder as is expended in a day; ſuppoſing a 24 pounder to fire 100 rounds in a day, and loaded with 8 pounds each time, requires 800 lb. or 8 barrels; and as a barrel is about 15 inches diameter, and 30 long, 3 bavins will cover one; and as they are placed one over another, 12 bavins will cover the powder of one 24 pounder.

As it is alſo neceſſary to ſupport the ends of the faſcines in the front, the others being laid upon the bank of earth, and an upright poſt when the magazine is large: they are ſometimes covered with planks when they can be had.

The length of platforms are commonly 18 feet, 8 broad before, 15 or 16 behind; the planks a foot broad, and from 2 to 2½ thick. The hurter to ſtop the wheels from

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from damaging the faſcines is 5 by 6 inches ſquare, and 8 feet long. There are five ſleepers to each platform to lay the planks upon, 3 by 4 inches ſquare, and 18 feet long; each ſleeper is faſtened by pickets drove faſt in the ground, two at each end, and two in the middle; and the laſt plank by 4 to keep them cloſe together: there requires then 34 pickets for each platform.

The faſcines muſt be well bound, thoſe of 6 feet by 3 bands, of 8 by 4, and of 10 by 5: the length of the pickets to pin down the faſcines muſt be from 3 to 5 feet, the diameters of the heads from 2 to 3 inches, well ſquared at the heads, and ſharp at the points. There are three required for a faſcine of 6 feet long, four for one of 8, and five for one of 10; which makes 590 pickets in all for a battery of two pieces.

A ſoldier may make 12 battery faſcines a day with the pickets required, when proper wood is to be had conveniently: a horſeman may make 20 bavins a day, bound in two places only, becauſe they require very little care to make them neat; for it is the cavalry that generally make theſe kind of faſcines.

Twelve ſoldiers will make a ſufficient quantity of faſcines in a day for a battery of two pieces, and three horſemen a ſufficient quantity of bavins at the ſame time. Each man muſt be provided with a hand-bill and two hatchets for the whole detachment to cut the branches from off the trees.

In the conſtruction of a battery of two pieces, it requires 10 mallets to drive the pickets, 15 ſpades, ſhovels, and pick-axes for digging, according to the nature of the ground. It has been found that 50 men are ſufficient to make a battery of two pieces in one night, 70, 90 for one of 4 or 6 pieces.

The following table contains the number of men, their tools and materials, to conſtruct in one night batteries from 2 to 20 pieces of cannon, as nearly as we could compute them; but as it is convenient to have ſome faſcines and pickets to ſpare, and to repair the battery,

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battery, we ſhall leave it to the engineer to make what allowance he pleaſes. We have not inſerted the number of faſcines and pickets required for the flanks; and if there are any, their number determined above muſt be added. We have neither marked the number of men or materials for batteries of an uneven number of pieces, becauſe they may be eaſily found, by taking half the ſum of the next greater and leſs, to have the number that is wanted.

Ricochet batteries.

Formerly batteries were made at the opening of the trenches to protect the workmen, but ſo ſoon as the firſt parallel was made they became uſeleſs; and as they are expenſive to make, and require much time and labour, this method has been rejected; and now none are made before the firſt parallel is finiſhed. Beſides, the approaches are now made the firſt night as far as the firſt parallel, and the parallel itſelf ſo far as to be finiſhed and perfected the next day; and when that is done, the batteries are erected about 100 yards before them perpendicular to the faces produced, which they are to enfilade: when they are compleated, do remain till the ſiege is finiſhed. Theſe batteries ſerve likewiſe to dismount the guns placed on the other faces nearly oppoſite to them.

As the beſieged will ſpare no pains to fire upon the workmen, and retard their conſtruction as much as they can, I would adviſe the engineer to continue the trenches of communication from the parallel to the battery by ſap quite round it, in taking care to leave a ſufficient ſpace for the ditch before the battery to get the earth for making the parapet: then the workmen may go on night and day till the whole is finiſhed with very little danger.

Theſe firſt batteries muſt be made as ſubſtantial as poſſible, in order to reſiſt all the fire the beſieged can bring

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bring upon them: as they are too far from the works of the fortification, they can ſcarcely be enfiladed, and therefore require no flanks.

Batteries on the glacis.

Theſe batteries are made to make a breach in ſome of the outworks, or in the faces of the baſtions, and to deſtroy the flanks; and as by this time the beſieged cannons have been or ſhould be diſmounted, except thoſe placed in the flanks, their parapets need not be above 10 or 12 feet thick; and as by this time the trenches are advanced upon the glacis within 12 or 15 feet of the covert-way, the batteries are placed in them; by which leſs labour, leſs materials, and leſs workmen are required: but as they are generally ſeen in the reverſe, they require flanks againſt the fire of ſmall arms.

Sometimes approaches are made uſe of to place batteries in them; in ſuch caſes they are widened backwards as far as is required for the recoil; and if the approaches are too deep, the bottom muſt be raiſed to a proper height with faſcines and earth to place the platforms upon them; and the parapet or breaſt-work muſt be made of a ſufficient thickneſs, and lined with faſcines in the ſame manner as mentioned before.

Mortar batteries.

They differ from the former in having no embraſures, and may be ſunk into the ground: ſo that whilſt the workmen without, throw the earth inward to make the parapet, others within, may work to throw the earth forward; by which the parapet is much ſooner compleated than thoſe of cannon: the inſide ſlope ſhould be conſiderable, that the bombardier may place two pickets, one at the top, and the other about the middle, in order to mark the line of direction for each mortar.

The

The platforms are about 6 feet ſquare, 8 diſtant from each other, and as much from the parapet, ſloping forwards, and are compoſed of 6 planks of 6 feet long, one broad, and 2 or 2.5 inches thick, 4 ſleepers, and about 28 pickets. As our mortar beds are made of ſolid timber, they commonly make a bed of gravel and ſand inſtead of a platform; but this method is diſapproved by the moſt experienced officers, eſpecially in ſieges.

When mortars are placed in the approaches, it is only widened ſo much as to have room for the loading and firing the mortar, and the earth dug up ſerves to heighten and thicken the parapet without any other preparations.

Battery in a moraſs.

To find a convenient ſpot of ground in ſuch ſituations, as likewiſe to make a road for the cannon and ammunition firm and ſecure, meets often with great difficulties, and ſeldom can be done but on or near the cauſeway that leads to the town; and if the place is properly fortified, it has always a flank that enfilades the cauſeway from one end to the other: in that caſe a battery muſt be raiſed near enough to diſmount the guns of the place, in order to carry on the approaches by zig-zagues on the cauſeway, till you come within a reaſonable diſtance to make a breach: the ſituation of the battery being fixed upon, faſcines, ſtone, and earth muſt be thrown in to make the foundation of the breaſt-work and platforms; when this is done to a proper height and levelled, the reſt of the parapet is finiſhed with gabions, ſome of 4 feet diameter, and as much in height; and others 3 feet high only for the embraſures.

It requires 10 for the firſt row in a battery of two guns, and 5 for the thickneſs of the parapet, that is, 50 gabions for the under bed. The row towards the town muſt be placed firſt, and filled with earth brought in baſkets and ſand-bags, or elſe theſe gabions muſt be ſtuffed with wood; then the next row is placed cloſe to

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to the firſt, and filled as quick as poſſible; and when another row is placed over the middle of the two firſt and filled, the workmen will be covered againſt the fire of the ſmall arms. When this is done the embraſures are marked, and gabions placed all round the merlons, beginning always with thoſe towards the place; or elſe the embraſures may be made with faſcines as before: and then the inſide or coffers may be filled with gabions, bavins, or faſcines, and earth to fill up the intervals, and make the parapet ſtrong and ſolid. If the height of two gabions is not ſufficient, faſcines and earth may be uſed to make up the deficiency.

The beds of the platforms are made with faſcines, and earth over them, ſo as to make it ſmooth and firm; and if that is not ſufficient, hurdles may be laid upon that bed, and more earth, and then the platforms in the manner as deſcribed before: when the whole is finiſhed, and the faſcine over the embraſures fixed, the gabions that maſk the embraſures are taken away, or elſe puſhed with a pole into the ditch before it, or ſo as not to prevent the ſeeing the defence of the place.

If there is no ſituation near the cauſeway where the battery can be placed to make a breach, or to diſmount guns which may ſee the breach, there is no other remedy than to carry a road made of faſcines, hurdles, and earth, either from the cauſeway, or the neareſt firm ground to the place where the battery is to be made.

It happens ſometimes that the ground where the battery can be made is ſeen by a ſuperior battery, that will diſmount the guns of yours; in this caſe a breaſt-work muſt be made at 20 or 30 paces before your battery, and embraſures cut in it ſo as that you may fire through, and prevent the beſieged from diſmounting your guns: this may always be done if there is ever ſo little bias, as it happened at *Oſtend*, when beſieged in the former war by the *French*. There was a ſpot of ground above the water, which overflowed all the adjacent ground when the tide was in: from this ſpot the harbour could

be

be enfiladed. Upon the fall of the adjoining baſtion to the harbour were placed fourteen 18 pounders, which bore obliquely upon the *French* battery of ſix 4 pounders; but by raiſing another breaſt-work about twenty paces behind the firſt, they fired during the whole ſiege into the harbour, without being ſeen or diſturbed by the ſuperior battery of the beſieged.

Battery upon a rock.

Such a ſituation is the moſt difficult of any, becauſe there is in many caſes no earth to be found but at a great diſtance, ſo that the parapet muſt be made with ſtuffed gabions and blocks of wood; the platforms partly cut out of the rock with pick-axes, and partly filled with earth and faſcines: and if the ſituation is ſeen by the beſieged guns, which can ſcarcely be avoided, and the battery not finiſhed in a dark night, it muſt be maſked with large trees or palliſades, otherwiſe the beſieged will pour all their fire upon the workmen, to make it in a manner impoſſible to finiſh it; ſince the ſplinters of the rock are no leſs dangerous than the ſhots.

If there is no road to the rock but what paſſes near the place, the firſt thing to be done is to convey the cannon and ammunition before the beſieged have any notice of your intention, otherwiſe they will oppoſe all they can to prevent it; and if they cannot, will render the paſſage ſo dangerous, as ſcarcely to make it practicable.

The ſituation of batteries is generally determined by the object to be battered, yet the advantage of the ground is often taken, ſuch as a hollow, hedge, buſhes, or old building, if the beſieged have neglected to clear the ground; but care muſt be taken that the battery is not too obliquely to make a breach, as it happened at *Carthagena* in 1742, where a battery of twenty 24 pounders was made in a copſe, and when finiſhed its ſituation was ſo bad, that after a week's firing the breach was ſo little, that a ſingle man could not mount it with-

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Number of Men, Tools, Faſcines, Pickets, and Planks for making BATTERIES, *from two to twenty Pieces of* CANNON, *in one Night.*

Numb. of Pieces.	Length of the Battery	Men to make the		Tools.	Faſcines in Feet.			Pickets.	Mallets	Hand Bills.	Platforms.			Bavins.
		Battery	Faſcin.		10	8	6				Planks.	Sleeper	Pickets.	
2	40 Feet	50	15	70	70	48	16	590	10	12	36	10	68	50
4	58	70	25	100	120	76	32	1000	18	16	72	20	128	100
6	76	90	35	130	170	104	48	1410	26	20	108	30	192	150
8	94	110	45	160	220	132	64	1820	34	24	144	40	256	200
10	112	130	55	190	270	160	80	2230	42	28	180	50	320	250
12	130	150	65	220	320	188	96	2640	50	32	216	60	384	300
14	148	170	75	250	370	216	112	3050	58	36	252	70	448	350
16	166	190	85	280	420	244	128	3460	66	40	288	80	512	400
18	184	210	95	310	470	272	144	3870	74	44	324	90	576	450
20	202	230	105	340	520	300	160	4280	82	48	360	100	640	500

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out being ſupported. At *Minorca* the *French* made a battery under cover of ſome empty houſes; and at the *Havannah* we made batteries againſt the fort *Moro* under cover of a wood. But when there is no cover, and you are obliged to make a battery near the enemy, the beſt method is to raiſe a great heap of earth by way of a cover, and make the battery behind it; and when it is finiſhed, the earth is puſhed forward in the ditch, if there is any.

To ſecure the gunners againſt the fire of ſmall arms whilſt they are loading the guns, ſhutters are made the width of the embraſures, either ſliding in grooves, or faſtened with hinges, ſo as to open or ſhut as occaſion requires. As to the reſt we refer the readers to our attack and defence, page 38, where they will find a plan, and a further explanation of every thing neceſſary not mentioned here.

PART VIII.

Calculation of the quantity of ARTILLERY *and* STORES *neceſſary for a field equipage.*

THE eſtimates of an equipage either for the field or a ſiege, which have hitherto been made, are intermixed with ſo many other things, which the duty of an artillery officer has no immediate connection with, that it is ſcarcely poſſible to diſtinguiſh the one from the other. It is true that theſe things are neceſſary in the field, but then I would mention them in ſeparate articles, and let the artificers determine what tools and materials each branch wants. We ſhall therefore compute here the quantity of artillery, ammunition, and ſtores; leaving the determination of the reſt to thoſe who are employed to do this buſineſs.

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The quantity of artillery required upon different occaſions depends on ſo many circumſtances, that nothing preciſely can be determined; not only the ſtrength of the army is to be conſidered, but likewiſe the particular circumſtances in regard to the action they are about; the nature and ſituation of the country; the ſtrength of places, whether ſea-port towns or inland, great or ſmall, ſtrong or weakly garriſoned; their quantities of guns and ſtores; in general, every thing that makes it neceſſary to have more or leſs artillery muſt enter into the determination before a reſolution can be taken. It was eſteemed formerly, that an army of 50000 men ſhould have 50 pieces of cannon, with all their appurtenances, and ſo more or leſs in proportion; but ſince that time a much greater number has been uſed, eſpecially now, when two field pieces are allotted to every battalion, beſides a ſeparate equipage, to be employed upon particular occaſions.

The manner of computing the quantity of powder and ſhot for an army.

It will be neceſſary that young officers ſhould know the manner and principles upon which the quantity of ſtores for an army are determined; for which reaſon we ſhall begin with the common light field pieces.

The 3, 6, and 12 pounders light, are commonly charged with a quarter of the ſhot's weight; therefore a 3 pounder requires for 100 rounds 75 pounds of powder, and 300 pounds of ſhot neat weight.

A 6 pounder for the ſame number of rounds, 150 pounds of powder, and 600 pounds of ſhot. The 12 pounder for the ſame number, 300 pounds of powder, and 1200 pounds of ſhot. The 24 light pounder is loaded with 5 pounds, therefore requires 500 pounds of powder for 100 rounds, and 2400 pounds of ſhot. Theſe four pieces, which are the only calibers uſed at preſent

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preſent in the field, require therefore 1025 pounds of powder, and 4500 pounds of ſhot for 100 rounds.

The long heavy pieces require a charge of one third of their ſhot's weight, and no more even for making a breach, as found by experience. Hence, a 3 pounder heavy requires 100 pounds of powder for 100 rounds; a 6 pounder 200; a 12 pounder 400; and a 24 pounder 800. Total 1500 pounds of powder, and the ſame number of ſhot as before.

The quantity of powder required for howitzes and mortars is uncertain; for it depends on the diſtances the ſhells are to be thrown.

Powder and ſhot for muſkets, carbines, and piſtols.

29 muſket bullets weigh 2 pounds; and hence 700 men, or a compleat battalion require 24 $\frac{4}{29}$ pounds of lead for one round, or 2407 pounds for 100 rounds; muſkets, carbines, and piſtols require a charge of powder for loading and priming, equal to half the weight of the bullets; therefore a battalion requires 1203 pounds of powder to fire 100 rounds.

20 bullets for carbines weigh a pound, whence 120 men, or a ſquadron of horſe require 600 pounds of ſhot for 100 rounds, and 300 pounds of powder. 34 bullets for piſtols weigh a pound; ſo that a ſquadron requires 176 pounds of lead, and 88 pounds of powder for 50 rounds.

Now if the ſtrength of an army is known, as well as the number of rounds allowed them in a campaign, it will be very eaſy to know the quantity of powder and bullets that is required. There is ſcarcely more rounds allowed than what we have mentioned here, which ſeems to be quite ſufficient for the foot, eſpecially when it is conſidered, that perhaps one third of an army does not act in an engagement. As for the horſe there is more than what is neceſſary, ſince their action conſiſts chiefly with the ſword, whilſt they are on horſeback; but as

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the dragoons fight alſo on foot in a cloſe country full of hedges and ditches, where the horſes cannot paſs, they may be ranked with the foot.

It has been found by experience, that a man may raiſe a weight equal to his own, and that he may carry or draw about 50 pounds to a moderate diſtance; and it has been found, that one horſe can draw as much as ſeven men *; therefore a horſe will draw or carry 350 pounds, though it is commonly ſuppoſed, that a horſe can draw but 300 for a length of time; and it is upon this ſuppoſition that the number of horſes required in the artillery is computed. We have found likewiſe that ſix men will draw a light 6 pounder in the field backwards and forwards.

Number of horſes.

Before we can compute the number of horſes, it is neceſſary to know the weight of each piece; from whence it appears, that a 3 pounder requires but 1 horſe, a 6 pounder 2, a 12 pounder 3, and a 24 pounder 6, of the light ſort; and the heavy 3 pounder 4 horſes, the ſix 7, the twelve 10, and twenty-four 17 or 18.

Therefore the number of horſes for a ſet of light pieces is 12, and the number for a ſet of the heavy 38, which is above three times more than the former; and from thence one may imagine how much expence is ſaved by making uſe of theſe light pieces in a campaign in this article alone, beſides what is ſaved in metal, workmanſhip, and in men to manage them.

Light Pieces.

Caliber.	Weight.
3	2 : 2 12
6	4 : 3 10
12	8 : 3 8
24	16 : 3 13

Heavy.

Caliber.	Weight.
3	11 : 0 : 0
6	19 : 0 : 0
12	29 : 0 : 0
24	51 : 1 : 12

* *Belid. Hydraul.* vol. i. p. 44. art. 123.

It

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It must be observed, that though horses may draw such a weight upon a common carriage, yet as those of guns are so injudiciously contrived, and the draught so disadvantageous, as we have shown in the construction of limbers, the 12 pounders and upwards require more horses than what we have set down here. But to give some idea of the number of horses required in the artillery, we shall set down here the number employed in the campaign of 1747, given to me by Colonel *Mirbelsen*, where the reader will find many articles that could not be known without experience; and from thence it may be guessed what would be necessary in sieges.

Number of horses used in the campaign of 1747.

Number		Each	Total
1	Kettle drum	4	4
2	Tumbrels	2	4
6	Twelve pounders	15	92
6	Nine pounders	11	66
14	Six pounders	7	98
26	Three pounders	4	104
2	Howitzes	5	10
20	Ammunition carts	3	60
2	Forge carts	2	4
30	Pontoons	7	210
3	Spare carriages for ditto	7	21

Spare carriages for guns.

1	Twelve pounder	7	7
1	Nine pounder	5	5
2	Six pounders	5	10
4	Three pounders	3	12

Spare limbers.

3	Twelve pounders	2	6

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3 Nine pounders		2	6
2 Six pounders		1	2
3 Three-poundors		1	3
Spare horſes			20
Total number of horſes			738

Baggage waggons for the officers.

	Waggons	Horſes
Colonel	3	10
Comptroller	3	11
Major	2	7
4 Captains	4	16
5 Captain Lieutenants	5	15
16 Lieutenants and Col. clerk	6	18
Quartermaſter	1	3
Surgeon	1	3
Paymaſter	1	3
Paymaſter's aſſiſtant and ſurgeon's mate	1	3
Chaplain and Compt. clerk	1	3
Commiſſary and waggon-maſter	1	4
2 Aſſiſtants to ditto	1	3
2 Commiſſaries of ſtores	2	6
2 Clerks of ſtores	1	3
Conductors of ſtores	2	6
Bridgemaſter	1	3
16 Engineers	12	36
5 Company's baggage	5	15
Contractors, artificers	6	18
Total	59	186

Waggons for ſtores.

Flag-waggon for the army and artillery guard	1	3

Picket

	Waggons	Horses
Picket and Provoſt	1	3
12 Pounders ſtores	9	27
9 Pounders ditto	7	21
6 Pounders ditto	12	36
3 Pounders ditto	10	30
40 Rounds for Howitzes and Petards	4	12
50 Rounds Royal, &c.	2	6
Ammunition for 35,000 men	122	360
Intrenching tools	24	72
Laboratory ſtores	2	6
Gin waggon	1	3
Small ſtores, artificers tools	20	60
Spare waggons	10	30
Total	225	675
From which is to be deducted		
20 Ammunition carriages	10	30
For three pair of boxes	12	36
Total	22	66
Remains	203	609
Add baggage waggons	59	186
Horſes for the guns		738
Sum total	262	1533

N. B. Several remarks are to be made on this account, in order to underſtand it rightly. The flag gun, which is a 12 pounder, had 17 horſes to draw it, although the reſt had but 15, which makes up the number 92 horſes for the ſix 12 pounders: with regard to the waggons, ſome were drawn by three horſes, and others by four; thus the comptroller had two waggons drawn by four horſes, and one by three. As to the ammunition carriages which were deducted, the colonel forgot on what account; all he remembers is, that they were either

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either detached, or were not brought into the field that campaign; but as to the number of horſes employed, the account is right. Hence it appears, that there are many things neceſſary, which can no otherwiſe be known than by practice. We ſhall therefore add an account of the ſtores carried into the field the ſame year, where the reader will find how neceſſary it is to ſtudy that branch of buſineſs, if he intends to be a compleat artilleriſt.

Stores for the army in 1747, *alphabetical.*

Aprons of lead			66
		Fore	Hind
Axle-tree bound, ſpare	12 pounders	1	2
	9	1	2
	6	1	3
	3	2	4
For tumbrels, forge, &c.			3
Axes	felling		150
	pick		1495
Bags for	ſhot, flints		634
	ſponges		60
Barrels, budge			20
Banners for kettle drum			2
Bayonets			840
Barrows	wheel		50
	hand		50
Beds for	guns		12
	mortars		7
Bills, hand			1499
Bridles for kettle drum chariot			4
Bruſhes for harneſs to ditto			4
Buckets of leather			36
Carriages, travelling with limbers, compleat	12 pounders		7
	9		7
	6		23
	3		26
For 8 inch howitzes			2

For

For pontoons		33
Cartridges, flannel, fixed with grape	12 pounders	180
	9	192
	6	560
	3	1040
For howitzes		20
Ditto with round ſhot	12 pounders	30
	9	30
	6	70
	3	130
Empty paper cartridges	12 pounders	650
	9	650
	6	1550
	3	2220
Cartridges for muſkets		76152
Carts	ammunition	20
	forge	2
Candles	wax lb.	50
	tallow	80
Crows, iron		15
Canteens		230
Caps for mortars		6
Cartouch boxes		1000
Chariot for kettle drum		1
Cloths	hair	24
	oil	2
Clouts, ſpare	body	104
	linch	100
Chains, draught	12 pounders	7
	9	7
	6	16
Chains for howitzes		2
Coals	char. buſhels	12
	ſea, ſacks	22
Colours, quarter, with ſtaves		40
Cord, whip lb.		1

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Coins	12 pounders	14
	9	14
	6	32
	3	34
	for howitzes	4
Couples for chain traces		500
Deals	whole	40
	ſtit	40
Drums, kettle, pair		1
Eſſes for draught chains		60
Flags	union	2
	red	1
Flambeaux, doz.		5
Flints	muſket	198510
	carbine	5720
	piſtol	10000
Formers for	12 pounders	1
	9	1
	6	1
	3	1
	muſkets	180
Forelock keys		423
Glue, lb.		6
Greaſe, firkins		33
Gins compleat		2
Hammers	claw	4
	ſmall	4
Hand ſpikes		148
Hand ſcrews		9
Hand grenades	fixed	2000
	empty	4000
Horſe harneſs	thill	95
	traces	404
	wanties	95
	bit halter	484
Harneſs for	kettle drum chariot, 4 to a ſet	1
	men, 12 to a ſet	40
Hatchets, hand		1030

Haverſacks

Haverſacks		216
Helves, ſpare, for pickaxes		100
Heads, ſpare, for kettle drums		2
Hemp rubbiſh, lb.		6
Hides tanned		42
Hooks, pairs	car	4
	ſling	4
Hoops, hazle		1000
Horns, powder		39
Howitzes		2
Irons	flat	5 : 0 : 12
	hoop	0
	rod	2 : 2 : 6
	ſquare	0 : 3 : 30
Iron priming, 4 to a ſet		60
Irons for marking horſes		3
Kettles, copper, with covers		40
Keys, ſpring		50
Ladles with ſtaves	12 pounders	6
	9	6
	6	20
	3	26
Ladles for 8 inch howitz		2
Lanterns	dark	6
	Muſcovy	6
	ordinary	6
	tin	12
Limbers ſpare	12 pounders	1
	9	1
	6	2
	3	3
	for howitzes	1
Links, dozens		12
Lines, Hamborough, lb.		60
Lint ſtocks	with cocks	60
	without	50
Locks, ſplinter, pad		80
Linch pins, pairs		56

Marlin

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Marlin	tarred, ſheets	42
	white	20
Mauls, large wooden		4
Match		29 : 0 : 27
Meaſures for powder, copper, from 3 lb. to ½ oz. from 8 oz. to ¼ ſets	12 pounders	1
	9	1
	6	1
	3	1
Meaſure for coals 1 buſhel		1
Medicines, cheſts		2
Mortars, coehorn		6
Moulds for	carbines	2
	piſtols	2
	muſkets	4
	ditto	6
Muſkets		925
Nails	40	20000
	30	2800
	20	6000
	10	5000
	6	4000
	4	4000
	clout	3500
	copper	300
	dog	500
	ſtreak	128
Ordnance, braſs	12 pounders	6
	9	6
	6	20
	3	26
Pannels for carrying mortars		6
Paper, fine, reams		2
Picket line, rope, 2 ½ inch coils		5
Pickets, park, ſhod		60
Petards fixed		12
Pails, wooden		6
Pontoons		30

Powder,

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Powder, corned, barrels		966
Rods for	musket	680
	carbine	100
	piſtol	200
Rings for forelocks		100
Ropes, drag	12 pounders	7
	9	7
	6	23
	3	30
	for howitzes	2
Rope tarred, 2 ½ inch feet		30
Ropes, white, coils	5 inch	1
	4	1
	3 ½	1
	2	1
Saws croſs cut		6
Scales, braſs, pairs		1
Screws for guns	12 pounders	6
	9	6
	6	20
	3	26
Shells, empty	8 inch	199
	5·5	294
Shells, filled	8	20
	5·5	120
Sheep-ſkins		117
Shovels		1000
Shot, lead	muſket, tons	58 : 19 : 1
	carbine	0 : 11 : 2
	piſtol	0 : 10 : 0
Shot, round	12 pounders	593
	9	599
	6	1390
	3	2594
Shot, grape	12 pounders	90
	9	90
	6	70
	3	750

Slings

Slings for guns, pairs		7
Spikes for ditto		300
Spades		1934
Sponges with rammers	12 pounders	6
	9	6
	6	20
	3	26
Ditto for	howitzes	2
	mortars	6
Staves for	flags	3
	ladles	50
Shot iron for grape		8000
Steel		1 : 2 : 16
Sticks for kettle drums, pairs		3
Stilliard with weight to weigh hundreds		1
Swing trees, pairs	12 pounders	7
	9	7
	6	14
	howitz	2
Tampeons, with collars	12 pounders	6
	9	6
	6	20
	3	26
	howitz	2
Tilts, wadmill		22
Tarpaulins		70
Tents	field officers	2
	captains	7
	ſubaltern	7
	horſemens	28
	French	140
	bell	13
	laboratory	2
Thread	fine	1
	pack, lb.	30

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Tools for artificers	carpenters chefts	3
	wheelers	3
	ſmiths	3
	tinmens	2
	collar-makers	2
	coopers	2
	miners	2
Tin tubes	12 pounders	214
	9	214
	6	500
	3	1300
Tumbrels		3
Twine, lb.		20
Tug-pins, ſpare, pairs		24
		Fore Hd.
Wheels, ſpare, pairs	12 pounders	1 : 2
	9	1 : 2
	6	1 : 2
	3	2 : 3
Ditto for	howitz	1 : 2
	forge or tumbrel	2
	ammunition waggons	2
Wad-hooks	12 pounders	6
	9	6
	6	20
	3	26
Waſhers, pairs		43
Weights, braſs		1
Whips for drivers		3

Laboratory ſtores.

Fixed fuſes	7 ¾ inches	250
	5 ½	3354
	hand	3000
Iron drills for fuſes	7 ¾	4
	5 ½	6
	hand	6

Hand

Hand mallets of ſorts for ditto	16
Small copper ladles { 7 ½	4
5 ½	6
hand	6
Setters of wood for fuſes	4
Mealed powder, lb.	210
Sulphur ſublimate, lb.	74
Compoſition for fuſes, lb.	25
Quick match, lb.	62
Port fires	1116
Rockets of 2 lb. for ſignals	12
Rods for ditto	12
Canvas, ells	60
Cotton wick, lb.	40
Spirits of wine, gallon	1
Cutting knives	10
Raſps with handles	6
Sciſſars, pairs	4
Pincers for fuſes	6
Small hand ſaws	6
Copper { ſalting-boxes	2
funnels for ſhells	2
Melting ladles of ſorts	4
Mealing table	1
Truſſes for ditto	2
Rubbers for ditto	2
Hand-bruſhes	4
Sieves with tops and bottoms dawn	2
Drawing knives	3
Quadrants	2
Machine to draw fuſes	1
Kitt { lb.	45
kettle	1
Laboratory cheſt, with padlock and key	1

I had this account from the Tower, but could have wiſhed that the particulars of each ſort had been in ſeparate articles, which we might have done, were it not

not that we thought the reader would be pleased to see the order and the particulars as cuſtomary.

Order of General BELFORD'S *march of the* ARTILLERY.

1. A guard of the army.
2. The company of miners, with their tumbrel of tools, drawn by 2 horſes.
3. The regiments of artillery front guard.
4. The kettle drums drawn by 4 horſes, and two trumpeters on horſeback.
5. The flag gun drawn by 17 horſes, and five 12 pounders more, by 15 horſes each.
6. Eleven waggons with ſtores for the ſaid guns, and one ſpare, by 3 horſes each.
7. Six 9 pounders drawn by 11 horſes each.
8. Nine waggons with ſtores for the ſaid guns, and one ſpare, by 3 horſes each.
9. Five long 6 pounders, by 7 horſes each.
10. Seven waggons with ſtores for ditto, and a ſpare one, drawn by 3 horſes each.
11. Five long 6 pounders, drawn by 7 horſes each.
12. Six waggons with ſtores for ditto, and a ſpare one, by 3 horſes each.
13. Four long 6 pounders, by 7 horſes each.
14. Five waggons with ſtores for ditto, and a ſpare one, by 3 horſes each.
15. Two howitzes, by 5 horſes each.
16. Four waggons with ſtores for ditto, by 3 horſes.
17. Six ſhort 6 pounders, by 2 horſes each.
18. Three waggons with ſtores for ditto, by 3 horſes each.
19. Six Royals with their ſtores in four waggons, by 3 horſes each.
20. One 12 pounder carriage, by 7 horſes; one 9 pounder carriage, by 5; one long 6 pounder carriage, by 5; two ſhort, by 2; one ſhort and one long limbers, by 1 horſe; and two forges, by 2 each.
21. Twenty

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21. Twenty ammunition carts, by 3 horſes each.

22. Nineteen waggons with muſket cartridges, and one ſpare, by 3 horſes each.

23. Thirty waggons with powder, and one ſpare, by 3 horſes each.

24. Thirty waggons with muſket ſhot, and one ſpare, by 3 horſes each.

25. Twenty-five waggons with intrenching tools, and one ſpare, by 3 horſes each.

26. Twenty-five waggons with ſmall ſtores, and one ſpare, by 3 each.

27. Six waggons for artificers, with 4 ſpare, each by 3.

28. Thirty-two baggage waggons, 9 by 4 horſes, and 23 by 3.

29. Thirty pontoons and 3 ſpare carriages, each by 7.

30. The artillery rear guard.

31. The rear guard from the army.

It muſt be obſerved, that there are parties of gunners and matroſſes marching with the guns; there are likewiſe ſome parties of pioneers interſperſed here and there to mend the roads, when they are ſpoiled by the fore carriages.

There was then 1415 horſes employed this campaign, 82 guns, 2 howitzes, 6 ſmall mortars, 244 waggons and carts, and laſtly, 30 pontoons; 20 of theſe laſt are eſteemed ſufficient for any part of *Flanders*, becauſe there is no river in this country that requires more to make a bridge over it.

The *French* march their artillery much in the ſame manner, but divide it into brigades, each of which is commanded by its proper officers, has a detachment of pioneers to aſſiſt in bad roads, as likewiſe a guard of gunners and matroſſes: the firſt brigade conſiſts always of ſome light pieces, followed by their proper ammunition, and preceded by a waggon loaded with tools, in

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in order to make and clear the roads, if there is any occaſion; a gin follows each diviſion loaded upon a ſpare carriage; the next brigade follows in the ſame order, and preceded with a carriage loaded with tools, with a detachment of pioneers.

The middle brigade conſiſts of the heavieſt pieces, and is called the park brigade; and as the others are only followed by ſo much ammunition as is ſufficient upon a ſudden occaſion, the reſt follow the park brigade. After this comes the baggage, and then the pontoons, with this reſerve, that if the army is to croſs a river, then as many pontoons march at the head as are ſufficient to make a bridge.

N. B. The front guns ſhould always carry 15 or 20 rounds in their lockers, to be ready to fire upon any ſudden occaſion, the pieces ſhould be loaded, and the gunners have their matches lighted during the march.

The detachments which march at the heads of the brigades, are to take care that the army baggage does not croſs the artillery, and the pioneers, if any carriage is overſet or ſtopt, to aſſiſt it; and in that caſe, word is given to the brigades before to ſtop, till all are ready to march, and when there is any ſtopping behind, thoſe before draw up cloſe at the ſide of each other, till the reſt come up, and then march on a common pace. Regularity and order ſhould be obſerved by all means to prevent confuſion, which is almoſt impoſſible where there are ſo many carriages.

It muſt be obſerved, that the heavy 24 pounders, or upwards, and the mortars, muſt be carried upon block carriages; for they would require too many horſes to draw them upon their own. Thoſe who want a farther inſight into theſe affairs, may conſult *S. Remy's* Treatiſe of Artillery, where they will find every thing explained in a very ample manner; and which we could not do in

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ſo ſmall a work as this. We intended to treat of the moſt eſſential part only, and ſuch as ſhould be known to moſt artillery officers, who expect to have a command.

To form a park of ARTILLERY. Plate XXVIII.

The artillery is generally placed about 300 paces before the middle of the firſt line of the army, upon ſome riſing ground, except a more convenient ſpot of ground happens to be before ſome wing; but let the ſituation be where it will, the manner of forming the park is the ſame, except that ſome artillery officers differ in the diſpoſition of the carriages. Some place all the cannon and mortars in the front, with their ſpare carriages; others are for dividing the equipage into brigades, and place the firſt in the front line, the ſecond into the next; and ſo on. But the beſt approved method is to divide the artillery into brigades, and to place the guns of the firſt to right of the front line, and their ammunition behind them in one or more lines; then thoſe of the ſecond brigade next to the firſt in the front, leaving five paces between them, and their ammunition behind them, as before; and continue placing all the reſt in the ſame order, the pontoons forming the laſt line. General *Belford*'s diſpoſition in the laſt war was:

The firſt line conſiſted of 32 guns mounted upon their carriages, ſeven ſpare carriages, 20 ammunition carts, and two howitzes; the guns pointing forwards.

The { ſecond line of 50 waggons.
third of 52 waggons.
fourth of 50 waggons.
fifth of 14 waggons, 30 pontoons, and three ſpare carriages.

Each carriage takes up two paces or yards, and they are placed at the ſame diſtance in the ſame line; the ſecond line is 30 paces behind the firſt; the two next 20 from each other; and the laſt 30 again.

The

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The artillery companies and miners are half incamped to the right, and the other half to the left of the park, in the usual manner, with some of the lieutenants in the rear of them.

In the rear of, and 12 paces from, the park are incamped the civil list all in one line; behind these, and at 30 paces distant, is a line of the remaining lieutenants; and behind these the captains and commissaries.

Opposite to the middle, and 30 paces behind the captain's line, is the major's tent; and behind this at 20 paces, the colonel's to the right, and the comptroller's to the left.

Opposite to the middle, and 50 paces before the park, is placed the army guard; and opposite to the right wing, the artillery guard at the same distance.

The *French* method is; the cart loaded with tools, which marches at the head, is placed to the right of the first line; next to that the guns of the first brigade, which commonly consists of 4 or 6 small pieces, with a spare carriage to the left of them; the ammunition carriages of this brigade are placed behind in one or more lines, at 30 paces distant from line to line. After this, the second and succeeding brigades are placed in the same manner, leaving five paces interval between the brigades: they continue thus to place all the guns, with their spare carriages, in the front line; the last line is made by the pontoons and other carriages.

S. Remy says, that seven pontoons will be sufficient to make a bridge over any river in *Flanders*; but I believe he did not mean the *Scheld* or the *Maese*, which seem to require more. It is however certain, that they carry no more than 20 pontoons and two spare carriages into the field; which is one third less than we do.

In the middle of the front two light pieces are advanced at a distance of 20 paces, loaded with powder for the alarm guns ready to be fired when required.

To the right of the park are placed the artificers, with their tools, materials, and baggage, in a line from

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the front to the rear. To the left of the park, the commiſſaries and their baggage; to the right of the artificers is incamped the firſt battalion of artillery, with their baggage and officers behind them in the uſual manner; and to the left of the commiſſaries, the ſecond battalion in the ſame manner as the firſt.

The horſes of the equipage are placed behind the firſt battalion, except thoſe of the picket in the rear of the park.

What has been ſaid here is ſufficient to give a clear idea of a park for a field equipage to a young officer; but, with regard to one before a town beſieged, we ſhall refer the reader to the works of *French* authors, who have wrote largely upon it.

REMARKS.

To determine the quantity of guns, ammunition, ſtores, and every thing elſe neceſſary in the field or a ſiege, ſo as to have enough, and no more, requires more knowledge and experience than can be found in one man. The *French* have a ſet of officers, whoſe buſineſs it is to manage theſe affairs; and who are gradually initiated into it. It is from their works that moſt nations of *Europe* copy the quantities of ſtores wanted upon different occaſions. As our commiſſaries of ſtores are taken into the ſervice when they are wanted, and diſcharged again ſo ſoon as the war is over, it is impoſſible we ſhould ever have any one capable of making a proper eſtimate, unleſs the artillery officers would undertake that branch of buſineſs, which they conceive not to be their duty; but, as they have more opportunities to be informed than any body elſe, and if any material article ſhould be wanted in an action they may be blamed, I imagine it would conduce much to their honour, and be at the ſame time for the public advantage, if they did. It was to aſſiſt them as much as in my power, that this work was wrote, which, by the help of experience,

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rience, will, I hope, be ſufficient to make an eſtimate of the moſt material articles, leaving the reſt to the artificers to determine the quantities of materials and tools they want, or to thoſe who have been employed in that buſineſs.

Before we leave this ſubject, we muſt take notice of ſome defects in our ſtore carriages. As there are a great number of them not ſo well contrived as they ſhould be, it not only increaſes uſeleſs expences, but likewiſe cauſes more trouble in the marching, and ſhould be avoided. Firſt, as our powder carts hold no more than four barrels, and a great quantity is required in all expeditions, they are not ſufficient; for which reaſon there ſhould be powder waggons to hold twelve barrels each. It is true, that the powder carts carry leaden bullets and flints at the ſame time; and are therefore more convenient to follow the battalions; but the reſt ſhould be carried in much larger quantities. The ſame thing may be obſerved in reſpect to all other carts; though they may be uſeful upon ſome particular occaſions, yet they ſhould not be uſed in carrying great quantities of any kind; for the whole weight lying upon one axle-tree, muſt require more horſes to draw a weight, than when the ſame weight lies upon two. This every carrier muſt know; and therefore no more carts ſhould be uſed than are neceſſary.

As to the pontoon carriages, we have obſerved, after their conſtruction, how unſkilfully they were made; the pontoons being twenty feet long, which is longer than any waggon, and yet are ſupported only by one axle-tree; therefore the ſhaft-horſe is hardly able to ſupport the weight laid upon it. As a pontoon cannot weigh above 1200 lb. with all its appurtenances, it appears very extraordinary, that there ſhould be ſeven horſes required to draw each, it can certainly be owing to no other cauſe than to the ill contrivance of the carriage: I would therefore make them with four wheels, and the fore ones but low, with a high bolſter, that it

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may turn with more eaſe in narrow roads; this being done, I am perſuaded, that four horſes would be ſufficient to draw them. The travelling forge is no better contrived than the pontoon carriages; for, when it is to be uſed, it is ſupported before by two props fixed to the ſhafts, which, by the leaſt accident, may give way, and down it goes. Nothing but the fondneſs for carts can excuſe ſuch a contrivance. [This has been remedied in ſome reſpect, as we have obſerved before.]

All carriages made uſe of in the artillery have ſhafts; and, to prevent the great length of thoſe that require a great number of horſes, the rule is to draw by pairs a-breaſt, which is an abſurdity no where elſe to be met with; for when the road is frequented by carriages drawn by two horſes a-breaſt, there is always a ridge in the middle, which the ſhaft-horſe, endeavouring to avoid, treads on one ſide, whereby the wheels catch againſt the ruts, and ſtop the carriage; and when the fore horſes bring them back, he treads on the other ſide, where the ſame happens again; ſo that the ſhaft-horſe, inſtead of being uſeful any otherways than to ſupport the ſhafts, becomes a hindrance to the reſt: on the contrary, if the road is frequented by carriages drawn by horſes all in a ſtring, the fore horſes muſt either tread in the ruts, or elſe the road muſt be quartered; and in that caſe the ſhaft-horſe muſt walk in the rut; conſequently, in all roads, except they are paved, either the ſhaft or the fore horſes muſt draw with all the diſadvantages poſſible. This has never been taken notice of by any of thoſe who have the direction of theſe affairs, though no carriages require more perfection in their conſtruction than theſe, on account of the great number wanting, and the heavy burthen that moſt of them are obliged to carry.

This defect may be remedied by making two pair of ſhafts in all four-wheel carriages, in the ſame manner as is done in waggons that carry great loads.

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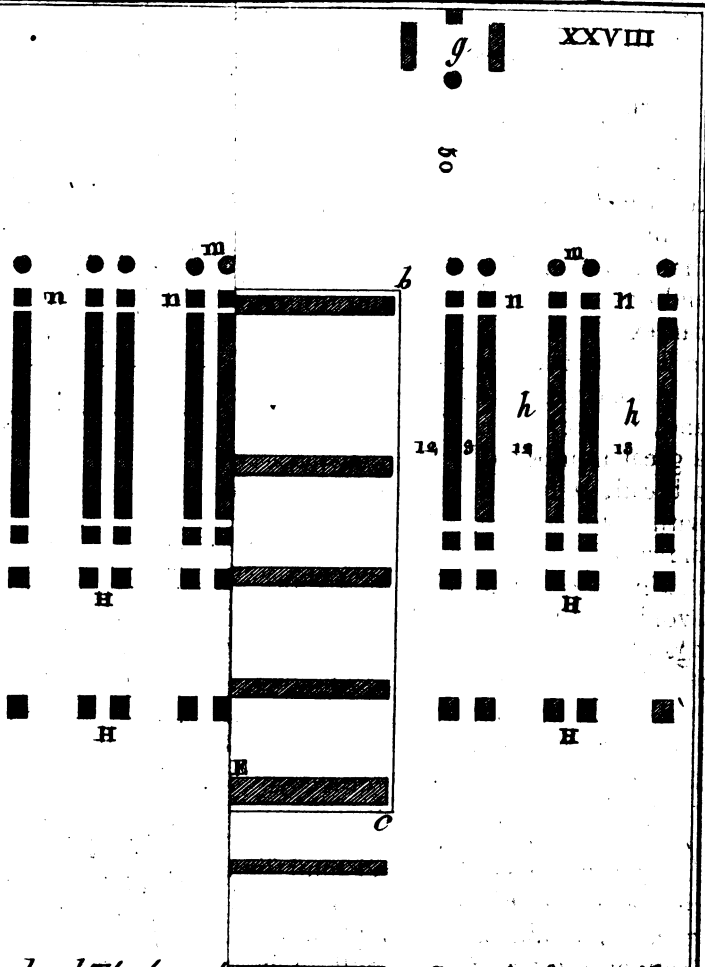
XXVIII



a b. c. d The bound… of the Park
f. The Army guar…
G. The Artillery g…
h. The Companies
G. The Civil List
H. The Lieutenants
K Captains & Commiss.rs
L The Majors Tent
M The Comptrollers Tent
N The Colonels Tent
A The Line of Guns
B.C.D.F The lines of waggons
E the line of Pontons

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Laboratory Works.

My deſign is not to give here any more than what is juſt neceſſary for the young artilleriſt to know in the courſe of his duty, referring that part which regards the fireworks made for rejoicing to the excellent Treatiſe on Artificial Fireworks, wrote by *Robert Jones*, Lieutenant in the Artillery, who gives all that can be ſaid on that ſubject, and has himſelf practiſed every part of it. Printed for *J. Millan.*

Grapeshot.

The number of ſhot in a grape varies according to the ſervice or ſize of the guns; in ſea-ſervice 9 is always the number; but by land it is increaſed to any number or ſize; from an ounce and a quarter in weight, to 3 or 4 pounds. It has not as yet been determined, that I know of, what number and ſize anſwers beſt in practice; which I think ought to be tried: for it is well known, that they often ſcatter ſo much, that only a ſmall number take place. It would not be a uſeleſs experiment, to try at what diſtance they would do moſt execution, and what is the beſt charge of powder. In ſea-ſervice, the bottoms and pins are made of iron, whereas thoſe uſed by land are of wood; for what reaſon this diſtinction is made, I cannot tell, unleſs that theſe iron bottoms are ſuppoſed to deſtroy the riggings of ſhips more than the wooden would do.

To make grapeſhot, a bag of coarſe cloth is made juſt to hold the bottom which is put into it; then as many ſhot as the grape is to contain; and with a ſtrong packthread they are quilted to keep the ſhot from moving: and when they are finiſhed are put into boxes for carriage, to be tranſported where-ever it is neceſſary. When the ſhot are very ſmall, they are put into tin boxes that juſt fit the bore of the gun. Leaden bullets are likewiſe

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uſed in the ſame manner. It muſt be obſerved, that whatever number or ſizes of the ſhots are uſed, they muſt weigh with their bottoms and pins nearly as much as the ſhot of the piece.

CARTRIDGES.

The loading and firing guns with cartridges is done much ſooner, and leſs liable to accidents, than with looſe powder. They are made of various ſubſtances, ſuch as paper, flannel, parchment, and bladders. When they are made of paper, the bottoms remain in the piece, and accumulate ſo much, that the priming cannot reach the powder; and therefore they muſt be drawn from time to time, which retards the ſervice. They have another inconveniency, which is, they retain the fire; and, if particular care is not taken in ſponging the piece, they will ſet fire to the next cartridge, and the gunner that puts it into the piece will be in danger of loſing a hand or arm, as has ſometimes happened. When they are made of parchment or bladders, the fire ſhrivels them up, whereby they enter into the vent, and become ſo hard, that the priming iron cannot remove them ſo as to clear the vent. Nothing has been found hitherto to anſwer better than flannel, and is the only thing uſed at preſent, becauſe it does not keep fire, and therefore not liable to accidents in the loading; but as the duſt of powder paſſes through them, a parchment cap is made to cover them, which is taken off before this is put into the piece.

The beſt way of making flannel cartridges is, in my opinion, to boil the flannel in ſize; this will prevent the duſt of the powder from paſſing through them, and renders them ſtiff, and more manageable; for without this precaution they are ſo pliable, that when they are large, and contain much powder, they are very inconvenient in putting them into the piece. The *Saxon*, who introduced our preſent light field pieces, had a particular method

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method of preparing cartridges, which was ſuch, that when laid into the fire they would not burn; and yet, by dipping them into water before they were put into the piece, would take fire as quick as powder; but how he did it nobody could tell; for he would not part with his ſecret.

In quick firing the ſhot is fixed to the cartridge by means of a wooden bottom, hollowed on one ſide ſo as to receive nearly half the ſhot, which is faſtened to it by two ſmall ſlips of tin croſſing over the ſhot, and nailed to the bottom; and the cartridge is tied to the other end of this bottom. They are fixed likewiſe in the ſame manner to the bottoms of the grapeſhot, which are uſed in field pieces.

PORTFIRES.

Portfires are uſed ſometimes inſtead of matches, to ſet fire to powder or compoſitions; and are diſtinguiſhed into wet and dry. The compoſition of wet portfires is, ſaltpetre 4, ſulphur 1, and mealed powder 4; when the compoſition is well mixed and ſieved, it is to be moiſtened with a little linſeed oil, and well rubbed with the hands till all the oil is well mixed with the compoſition. The compoſition of dry portfire is, ſaltpetre 4, ſulphur 1, mealed powder 2, and antimony 1. Theſe compoſitions are drove into ſmall paper caſes, and ſo kept till they are uſed.

QUICKMATCH.

It is made with three cotton ſtrands drawn into length, and put into a kettle juſt covered with white wine vinegar, and then a quantity of ſaltpetre and mealed powder is put in it, and boiled till well mixed. Others put only ſaltpetre into the water. After that, it is taken out hot, and laid into a trough where ſome mealed powder, moiſtened with ſpirits of wine, is thoroughly wrought

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wrought into the cotton, by rolling it backwards and forwards with the hands: when this is done, they are taken out ſeparately, and drawn through mealed powder, then hung upon a line till dry.

TUBES *uſed in quick firing.*

Theſe tubes are here made of tin: their diameter is two tenths of an inch, which is ſo as juſt to enter into the vent of the piece; about 5 or 6 inches long, with a cap above, and cut ſlanting below in the form of a pen; and the point is ſtrengthened with ſome ſolder, that it may pierce the cartridge. Through this tube is drawn a quickmatch, and the cap is filled with mealed powder moiſtened with ſpirits of wine. To prevent the mealed powder from falling out by carriage, a cap of paper is tied over it, which is taken off when uſed; but latterly this cap is made of flannel ſteeped in ſpirits of wine, and with ſaltpetre diſſolved in it; and there is no occaſion to take it off, ſince it takes fire as quick as looſe powder.

An objection is made againſt theſe tubes, which is, that the tin is apt to ſpoil the quickmatch when they are kept for ſome time; and it is imagined, that ſalt water would ſoon corrode them, and therefore not proper to be uſed on board of ſhips; this however has not been tried as I know of. The *French* uſe a ſmall reed, to which is fixed a wooden cap about two inches long; they are filled with mealed powder moiſtened with ſpirits of wine, and a ſmall hole is made through them the ſize of a needle, through which the fire darts with great violence, and gives fire to the cartridge, which muſt be pierced beforehand with the priming iron. Theſe tubes may be kept a great while without being ſpoiled; but the piercing the cartridge retards the quickneſs of firing. The forementioned *Saxon* made his of copper, tapering towards the end, ſo as to enter the vent about half an inch, which is made ſo far in the ſame form, and the reſt

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reſt very narrow: they are filled in the ſame manner as the *French*, and when fired, the flame darted through the cartridge without being pierced.

FUZES *for ſhells and hand-grenades.*

The compoſition for fuzes is ſaltpetre 3, ſulphur 1, and mealed powder 3, 4, and ſometimes 5, according as it is required to burn quicker. Fuzes are chiefly made of very dry beech-wood, and ſometimes of hornbeam taken near the root; the upper part of that wood ſplits very eaſily. They are turned rough, and bored at firſt, and then kept for ſeveral years in a dry place: the diameter of the hole is about a quarter of an inch, a little more or leſs is of no conſequence; the hole does not go quite through, leaving about a quarter of an inch at the bottom; and the head is made hollow in the form of a bowl. The compoſition is drove in with an iron driver, whoſe ends are capped with copper to prevent the compoſition from taking fire; and equally hard as poſſible; the laſt ſhovel-full being all mealed powder, and two ſtrands of quickmatch laid acroſs each other being drove in with it, the ends of which are folded up into the bowl, and a cap of parchment tied over it till uſed. It will not be improper to obſerve, that, when ſhells are to be thrown at a ſmall diſtance, the compoſition ſhould be made quicker than when they are to be thrown at a greater; for, by cutting them ſo as to burn but a ſhort time, they might not be long enough to be well fixed into the ſhell, by which the blaſt of the powder in the chamber would blow them out, without the ſhell being able to burſt. It muſt likewiſe be obſerved, that the cuſtom of fixing the ſhells at home is very bad; ſince it is not known how long they ſhould burn; and, if they do not burſt as ſoon as they fall, the execution is but trifling. Another diſadvantage attends this practice; when they are carried into a hot climate the wood ſhrinks, though ever ſo dry before; and the fuzes looſen

ſo

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ſo much, that they fall out in the flight of the ſhell before it falls to the ground.

When the fuzes are to be drove, the lower end is cut off in a ſlope, ſo as the compoſition may give fire to the powder; and they muſt have ſuch a length as to burſt nearly as ſoon as the ſhell touches the ground. When the diſtance of the battery from the object is known, the time of the ſhell's flight may be computed nearly; which being known, the fuze may be cut accordingly, by burning two or three, and making uſe of a watch or a ſtring by way of a pendulum.

Before ſhells are loaded, they muſt be well ſearched within and without by means of a copper grater, to ſee whether there are no holes or cavities in them; after that they are put into a tub of water, ſo as to cover them, with an empty fuze drove into them; and the mouth of a bellows, being introduced into the fuze, and worked, will cauſe bubbles in the water, if there are any holes in the ſhell; but if no bubbles appear, it is a ſign the ſhell is ſound and fit for ſervice.

When they are loaded, care muſt be taken that they are very dry within; and if the ſpike which ſupports the corp when they are caſt, and which remains in them, is not beat down, it muſt be done then, otherwiſe it would ſplit the fuze. Then the powder is put into it with a funnel, and not quite filled, that the fuze may have room to enter, which fuze is preſſed in at firſt by the hand as far as it will go, and then drove with a mallet as hard as poſſible, taking care however not to ſplit it; for if the leaſt crack was in it, the compoſition would give fire to the powder, and the ſhell would burſt either in the mortar or in the air, and ſo do no execution.

It is a query how much powder is to be put into a ſhell, ſo as to make it burſt in moſt pieces? It is agreed by moſt officers that they ſhould not be quite filled; one that has taken moſt pains to find it out is of opinion that they

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they ſhould be filled within one third part of what they can hold.

Lieutenant *Pirle*, a very ingenious mechanic, loſt in the *Dodington* ſome years ago going to the *Eaſt-Indies*, had found out a method, ſo that as ſoon as the ſhell touched the ground it burſted; but being too modeſt a man, had not the aſſurance to propoſe it to the maſter general of the ordnance, whereby the world was deprived of ſo uſeful an invention.

If the fuſes are to be kept for ſome time after they are drove, the top muſt be covered with a mixture of pitch 2, roſin 1, and bees wax 3, whereby no air can come to the compoſition; and it will keep as long as you pleaſe.

CARCASSES.

None but round carcaſſes are uſed at preſent, the flight of the oblong are ſo uncertain, that they have been quite laid aſide. The compoſition is pitch 2, ſaltpetre 4, ſulphur 1, and corned powder 3. When the pitch is melted, the pot is taken off, and the ingredients well mixed put in; then the carcaſs is filled with as much as can be preſſed in.

Light BALLS *to diſcover the enemy's works.*

There are various ſorts deſcribed by different authors. Some are made of tow dipped into a compoſition of ſulphur, pitch, roſin, and turpentine; and worked up all together into a ball. Others take a ball of ſtone or iron, which is covered with ſeveral coats of compoſition much like that before-mentioned, till of a proper ſize; and the laſt coat is to be of grained powder. But the beſt ſort, in my opinion, is to make a ſhell of paper the ſize of the mortar, and to fill it with a compoſition of an equal quantity of ſulphur, pitch, roſin, and meaſed powder; which being well mixed, and put in warm, will give a clear fire, and burn a conſiderable time.

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There are many more things uſed in the defence of a breach; ſuch as ſacks filled with powder, bottles, barrels, &c. but as the chief intent of all theſe is to ſet fire, and blow up the aſſailants, and which every military gentleman may eaſily execute, we ſhall ſay no more here about them; our deſign being only to inſtruct the young artilleriſt in the moſt eſſential parts of his buſineſs; and to make him maſter of theſe matters, he muſt work in the laboratory; for practice is the beſt maſter.

FIRESHIP, *how to prepare it.*

From the bulkhead at the forecaſtle to a bulkhead to be raiſed behind the main chains, on each ſide and acroſs the ſhip at the bulkheads, is fixed cloſe to the ſhip ſides, a double row of troughs, two feet diſtance from each other, with croſs troughs quite round, at about two feet and a half diſtance; which are mortiſed into the others. The croſs troughs lead to the ſides of the ſhip, to the barrels, and to the port-holes, to give fire both to the barrels and to the chambers, to blow open the ports; and the ſide-troughs ſerve to communicate the fire all along the ſhip and the croſs troughs.

The timbers of which the troughs are made are about five inches ſquare; the depths of the troughs half their thickneſs, and they are ſupported by croſs pieces at every two or three yards, nailed to the timbers of the ſhip, and to the wood-work which incloſes the fore and main maſts, and takes in an oblong in the middle of the deck, extending to the outſide of both the maſts, and in breadth is near one half of the deck; and is what makes the carpenter's room for his ſtores. The decks and troughs are all well paved with melted roſin.

On each ſide of the ſhip are cut out ſix ſmall port-holes, in ſize about 15 by 18 inches, the ports opening downwards, and are cloſe caulked up: againſt each port is fixed an iron chamber, which, at the time of firing the ſhip, blows open the ports, and lets out the fire.

At

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At the main and fore chains on each ſide is a wooden funnel fixed over a fire barrel, and comes through a ſcuttle in the deck up to the ſhrouds to give fire to them; and between them are cut two ſcuttles on each ſide the ſhip, which alſo ſerve to let out the fire. Both funnels and ſcuttles muſt be ſtopt with plugs, and have ſail-cloth or canvas nailed cloſe over them, to prevent any accident happening that way by fire to the combuſtibles below.

The port-hole, funnels, and ſcuttles, not only ſerve to give the fire a free paſſage to the outſide and upper parts of the ſhip, and its rigging, but alſo for the inward air, otherwiſe confined, to expand itſelf, and puſh through thoſe holes at the time of the combuſtibles being on fire, and prevent the blowing up the decks, which otherwiſe muſt of courſe happen from ſuch a ſudden and violent rarefaction of the air as will then be produced.

In the bulkhead behind on each ſide is cut a ſmall hole, large enough to receive a trough of the ſame ſize as the others; from which, to each ſide of the ſhip, lies a leading trough, one end coming through a ſally port cut through the ſhip's ſide; and the other, fixing into a communicating trough that lies along the bulkhead, from one ſide of the ſhip to the other, and being laid with quickmatch only, at the time of firing either of the leading troughs, communicates the fire in an inſtant to the contrary ſide of the ſhip, and both ſides burn together. The communicating trough, which is fixed to the bulkhead, and the leading troughs, are the ſame ſize as the others.

Manner of preparing STORES.

FIRE-BARRELS.

The form of the barrels ſhould be cylindric, both upon the account of that make anſwering better for filling

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filling them with reeds, and for ſtowing them on board between the troughs; their inſide diameters are ſufficient, if about 21 inches, and their lengths 33. The bottom parts are firſt filled with ſhort double dipt reeds ſet on end, and the remainder with fire-barrel compoſition well mixed and melted, and then poured over them.

There are 5 holes of ¾ inches diameter, and 3 inches deep, made with a drift of that ſize in the top of the compoſition while it is warm; one in the center, and the other four at equal diſtances round the ſides of the barrel. When the compoſition is cold and hard, the barrel is primed by well driving thoſe holes full of fuze compoſition to within an inch of the top; then fixing in each hole a ſtrand of quickmatch twice doubled, and in the center hole two ſtrands the whole length; all which muſt be well ſet or drove in with mealed powder; then lay the quickmatch all within the barrel, and cover the top of it with a dipt curtain, faſtened on with a hoop to ſlip over the head, and nailed on.

The barrels ſhould be made very ſtrong, not only to ſupport the weight of the compoſition before firing, in removing and carrying them about, but to keep them together at the time they are burning; for if the ſtaves are too ſlight and thin, and ſhould burn too ſoon, ſo as to give way, the remaining compoſition would be apt to ſeparate, and tumble upon the deck, which would deſtroy the deſigned effect of the barrel, which is to carry the fire aloft.

IRON CHAMBERS.

They are 10 inches long, and 3.5 in diameter; and breeched againſt a piece of wood fixed acroſs the port-holes, and let into another lying a little higher; when loaded they are filled almoſt full of corned powder, and have a wooden tompion well drove into their muzzles; are primed with a ſmall piece of quickmatch thruſt through

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through their vents into the powder, with a part of it hanging out; and when the ſhip is fired, they blow open the ports; which either fall downwards, or are carried away, and ſo give vent for the fire out of the ſides of the ſhip.

CURTAINS

Are made of barras about ¾ of a yard wide, and one yard in length; when they are dipped, two men with each a fork (on a ſhaft of the ſame ſize, with one prong in each if made on purpoſe) muſt run each of their prongs through a corner of the curtain at the ſame end; then dip them into a large kettle of compoſition well melted; and when well dipped, and the curtain extended to its full breadth, whip it between two ſticks of about 5.5 feet long, and 1.5 inches ſquare, held cloſe by two other men to take off the ſuperfluous compoſition hanging to it; then immediately ſprinkle ſaw-duſt on both ſides to prevent its ſticking, and the curtain is finiſhed.

N. B. A copper fixed with a furnace is much better than a kettle that is not fixed, becauſe it muſt be taken off from the fire for every dipping, to prevent the ſtripped off compoſition from falling into it, which would unavoidably give fire to the whole; and renders the uſe of a kettle tedious that way.

REEDS

Are made up in ſmall bundles of about 12 inches in circumference, cut even at both ends, and tied with two bands each; the longeſt ſort is 4 feet, and the ſhorteſt 2.5; which are all the lengths that are uſed. One part of them are ſingle dipped, only at one end; the reſt are double dipped, that is, at both ends. In dipping, they muſt be put about 7 or 8 inches deep into a copper or kettle of melted compoſition; and when drained a

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little over it, to carry off the ſuperfluous compoſition, ſprinkle them over a tanned hide with pulveriſed ſulphur, at ſome diſtance from the copper.

BAVINS

Are made of birch, heath, or other ſort of bruſh-wood, that is both quickly fired and tough; in length 2.5 or 3 feet, the buſh-ends all laid one way; and the other ends tied with two bands each. They are dipped and ſprinkled with ſulphur the ſame as reeds, only that the buſh-ends alone are dipped, and ſhould be a little cloſed together by hand as ſoon as done, before they are ſprinkled, to keep them more cloſe, in order to give a ſtronger fire, and to keep the branches from breaking off in ſhifting and handling them.

DISPOSITION *of the* STORES *on board, when laid for firing.*

The fire-barrels are placed under the funnels and ſcuttles, one to each; and are fixed between the croſs troughs leading to the ſides of the ſhip, and laſhed to them, and well cleeted to the deck. Thoſe at the funnels give fire to the main and fore ſhrouds; the reſt riſes over the deck through the ſcuttles. The plugs muſt be taken out of the funnels and ſcuttles before the ſhip is fired, and the curtains covering the fire-barrels cut open and rolled back, the quickmatch ſpread, and the top of the barrels well ſalted with priming compoſition. The curtains are nailed to the beams of the upper deck, hanging down over the troughs, bavins, and reeds.

The priming compoſition; a part of it is laid along the troughs, and the reſt, after laying of the reeds and bavins, is regularly ſtrewed over all. The ſhort reeds double dipped, with ſome of the ſingle dipped, are laid along both the ſides and croſs troughs, and communicate the

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the fire both to the barrels and chambers. The reſt of the ſingle dipped reeds and bavins are ſet about the fire-barrels, and to the ſides of the ſhip; and ſome flung upon the deck.

The quickmatch is laid two or three ſtrands thick upon the reeds in the troughs, and about the fire-barrels and chambers, to communicate a general fire at once. The reeds in the troughs with the quickmatch are laſhed on, to prevent their falling out by the rolling of the ſhip.

The leading troughs are both laid with 4 or 5 ſtrands of quickmatch; as is likewiſe the communicating trough, that, by firing either of the leading troughs, the communicating trough may carry the fire to the other ſide of the ſhip; which then runs along the troughs by the quickmatch on both ſides, and give fire to the whole in an inſtant.

The COMPOSITION *made uſe of for* CURTAINS, REEDS, *and* BAVINS, *are all the ſame, viz.*

Pitch	14
Sulphur	7
Roſin	7
Tallow	2
Tar	1

N. B. For want of tar, take 3 lb. of tallow.

Fire-Barrel COMPOSITION *for one* BARREL.

Corned powder lb.	120
Pitch	60
Tallow	19

Divide the compoſition into five pots; the pitch and tallow muſt be firſt thoroughly melted. Tallow well the outſide of the pot to take off the heat; and then put in the powder by ſmall quantities, ſtirring it well about.

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Priming COMPOSITION *for one* BARREL.

Corn powder lb.	100
Petre	50
Sulphur	40
Roſin	6
Oil, pints	3

Take 20 lb. of powder, which mix well with the petre, ſulphur, and roſin, work them well together, breaking it well in working; then put the reſt of the powder in by degrees, and work it altogether: ſpread it in a trough, and through a hair ſieve run 3 pints of oil all over it; then work it well together, and run it through a cane ſieve.

N. B. In the following eſtimate for the quantity of ſtores requiſite, the reeds for the barrels are not included; it will take 100 ſhort double dipped more than theſe ſpecified; but their value is included in the article of barrels.

STORES *for a* FIRESHIP *of* 150 *tuns.*

	Numb.	Value.
		l. *s.* *d.*
Fire barrels	8	80 : 0 : 0
Iron chambers	12	12 : 0 : 0
Priming compoſition barrels	3½	21 : 0 : 0
Quickmatch barrels	1	3 : 0 : 0
Curtains dipped	30	3 : 0 : 0
Long reeds ſingle dipped	150	10 : 15 : 0
Short reeds { double dipped	75	2 : 18 : 9
Short reeds { ſingle dipped	75	1 : 17 : 6
Bavins ſingle dipped	209	10 : 0 : 9
		144 : 11 : 3

Quantity

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Quantity of COMPOSITION *for preparing the* STORES *of a* FIRESHIP.

	pe-tre.	ſulp	coin pow.	pit ch	ro-ſin	tal-low	tar	oil pts.
For 8 barrels — —	0	0	960	480	0	80	0	0
For 3. 5 barrels of priming compoſition — —	175	140	350	0	21	0	0	11
For the curtains, bavins, and reeds for the ſhip, and ſulphur for ſalting them — —	0	200	0	350	175	50	25	0
Total —	175	340	1310	830	196	130	25	11

Total weight of the compoſition 3017 equal to C. 26 : 3 : 2.

Compoſition allowed for the reeds for the barrels one fifth of the whole of the laſt article, which is equal to 160 lb. and makes the whole 3177 pounds, or C. 28 : 1 : 13.

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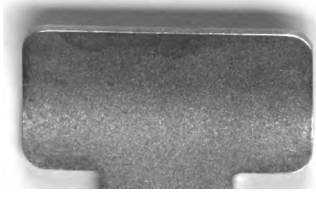

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